Using SCIENCE

SMITH • TRAFTON

Courtesy Society for Visual Education, Inc.

The beautiful tiger, like other members of the cat family, is a graceful, efficient killer.

★ ★ ★

Using SCIENCE

by

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PREFACE

Content. The content of The Science in Modern Life Series is functional. It deals with the everyday surroundings of the child and with the grown-up world into which he will move. The selection of content is based upon study of syllabi representing the most progressive cities and states. Major concepts demanded by a significantly large number of the syllabi have been made the basis of the three books—*Exploring Science, Enjoying Science,* and *Using Science.* In addition, up-to-date material on transportation, housing, communication, and other vitally interesting and important activities has been included.

Grade placement. The series is graded upon three bases. First, a comprehensive study was made of scientific concepts and their difficulty. As a result, subject matter was divided according to its difficulty into three large blocks—the simplest material being assigned to the first book, the most difficult to the third. Some adjustment was made for the sake of logical organization. Second, a careful check of vocabulary was made, following the findings of Curtis, based upon *Teachers' Word List* by Thorndike. Third, a natural sequence of scientific thought was worked out, based upon the complexity of relationships. For example, understanding the stove precedes the study of air conditioning.

Organization. The organization of the series follows the psychological unit method. Each unit is truly a significant and comprehensive cross section of human experience. The problems, which are developed to contribute to understanding the unit, can be studied at the rate of one per day, a factor of major importance when one day or much longer periods may intervene between meetings of the class. The unique review of the unit is designed to emphasize scientific thinking by giving the child practice in relating his knowledge to major principles.

Amount of material. The amount of material in each book is adequate for one year of work. The teacher will find it unnecessary to "pad out" the course with extensive busy work or review.

Study aids. Many study aids are included. The daily test exercises at the ends of problems and the review exercises at the ends of units encourage mastery. Difficult words are defined and

pronounced in the text where they occur. Questions and directions for observation assure attention to demonstrations. In the average classroom situation, no workbook will be needed.

DEMONSTRATIONS. Demonstrations are graded and practical. Every demonstration can be done either with standard laboratory equipment or with materials which can easily be obtained by the pupils. Elaborate setups are intentionally avoided.

VISUAL AIDS. Visual aids are listed where they are to be used—filmstrips at the end of the problems, motion pictures at the end of the units. These aids to learning are of utmost importance in modern education.

ACTIVITIES. "Science activities for fun" constitute an important means of helping the child to participate in the learning experiences. These may be done either at school or at home and stimulate the child's interest in learning by doing.

UNIT ARRANGEMENT. The cyclic arrangement of the units fits modern understanding of child growth. Since the young person is constantly interested in his whole environment, the cyclic organization is the only one which makes it possible to meet his needs. Repetition is avoided by the increasing difficulty of the concepts presented and by varying the approach of unit organization in the third book.

Exploring Science, Enjoying Science, and *Using Science* may be used as science readers in schools where a complete science program is impossible, for the text of each problem is unbroken by activities that cannot be done as the text is read.

The authors wish to acknowledge the helpful assistance of the following individuals and organizations.

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The dozens of teachers who have assisted in testing materials, the many friends who have read manuscript and offered suggestions, the thousands of pupils who have submitted to the tests with at least a fair degree of enthusiasm, and the many people who have contributed to courses of study, educational research, and scientific literature—all have made a direct and valuable contribution to The Science in Modern Life Series.

Note: The government filmstrips (those marked U.S.D.A.) may be obtained from Dewey and Dewey, Kenosha, Wisconsin. The remainder of the filmstrips may be obtained from the Society for Visual Education, 100 East Ohio Street, Chicago, Illinois.

KEY TO THE SOUNDS OF WORDS

In this book there are many scientific words which you should know how to pronounce. Their pronunciations are given in brackets like this: [ ]. These pronunciations are put in the sentences right after the words, so you can learn them the first time they appear. The following table shows the marks that are used:

ā as in āble
ā̇ as in chā̇otic
â as in câre
ă as in ădd
ă as in *ă*ccount
ä as in ärm
ȧ as in ȧsk
ȧ as in sof*ȧ*

ou as in out
oi as in oil

ē as in ēve
ē̇ as in ē̇vent
ĕ as in ĕnd
ĕ as in sil*ĕ*nt
ẽ as in makẽr

ī as in īce
ĭ as in ĭll
ĭ as in char*ĭ*ty

ū as in cūbe
ū̇ as in ū̇nite
û as in ûrn
ŭ as in ŭp
ŭ as in circ*ŭ*s
ü as in menü

ō as in ōld
ō̇ as in ō̇bey
ô as in ôrb
ŏ as in ŏdd
ŏ̂ as in sŏ̂ft
ŏ as in c*ŏ*nnect

o͞o as in fo͞od
o͝o as in fo͝ot

ch as in chair
g as in go
ng as in sing
t̶h̶ as in t̶h̶en
th as in thin
t͜ū as in nat͜ūre
d͜ū as in verd͜ūre
y as in yet
zh = z as in azure

The accented syllable is marked ′. ʹ shows a secondary accent.

There are many words in the book which are explained, or defined, for you, also. These definitions usually are found at the place in the text where the word first appears. Of course you will want to use a dictionary sometimes to help you learn *all* the meanings of a word.

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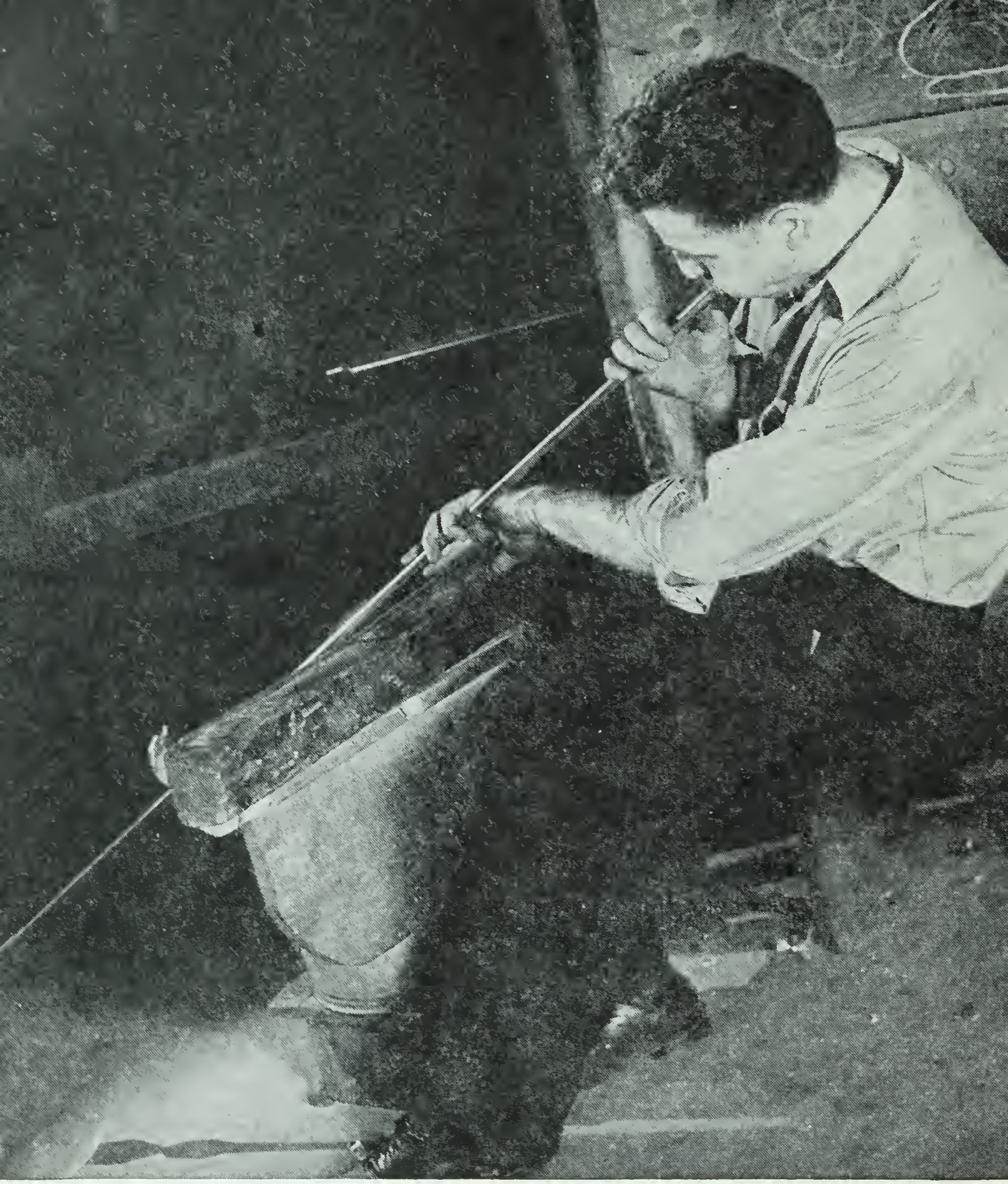
USING SCIENCE



Courtesy Steuben Glass, Inc.

UNIT ONE

WHY IS THE STUDY OF SCIENCE NECESSARY?

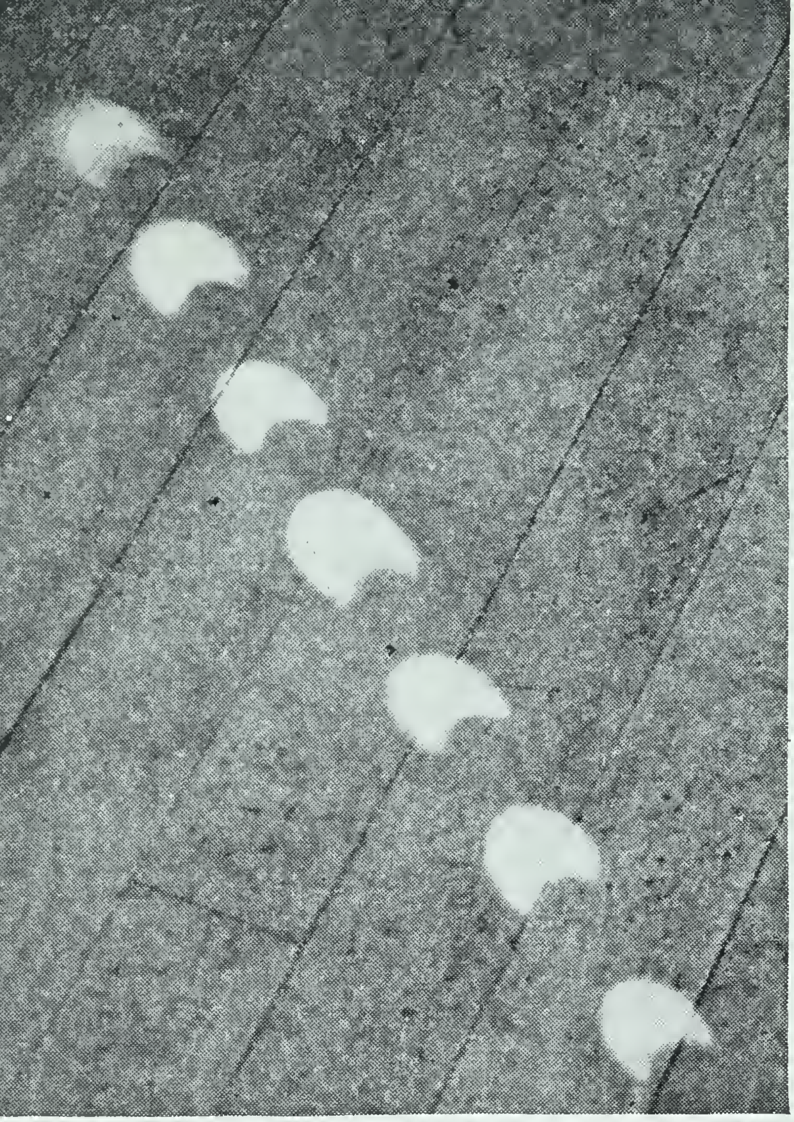
OVER the radio came an amazing story of a man who dreamed in complete detail about the occurrence of a steamship accident. Then, having forgotten the incidents of his dream, he boarded a boat two weeks later, and the accident of his dream was repeated in reality before his eyes. Dates were given; names and addresses of the people involved were stated exactly. The dream was explained by the radio announcer as another marvelous display of the power of the supernatural.

You will encounter incidents similar to this throughout your life. You will often be asked to believe tall stories of unreasonable events, all of which are supported in full by details looked up after the story was started or invented by the mind of some imaginative person. If you are not careful you will find yourself impressed by the seemingly reasonable explanations until you believe what you know is not true. How can you protect yourself from the ignorance which you see around you?

The best remedy for ignorance and superstition is knowledge based upon correct methods of observation, measurement, and experimenting. You must learn to apply to your facts the processes of careful reasoning. The careful thinker withholds judgment until information is tested many times.

You will find as you study science that your ideas about many common beliefs are gradually changing. Some ideas you will test and discard; others you will be able to prove are sound. You may for a time lose confidence in knowledge, for you find that some things you once thought were true are really not based upon fact. But you should gain confidence in your ability to think as you go through these experiences.

Society is controlled by the majority of the people in any country. Unless you as a member of society are careful to apply to social problems the same calm judgment that you are asked to use in the science classroom, society will suffer. It is not enough to disbelieve foolish notions. You must learn to think through these foolish ideas and to expose their errors, not only to yourself but to others. You have a responsibility to yourself and to others to develop correct processes of thinking. The only kind of correct thinking is scientific thinking.



One rarely sees an image of the sun in eclipse upon the floor. These images were projected through tiny openings at the side of a Venetian blind. Knowledge of science enables one to understand his environment.

1. What is the method of scientific thinking?

If you were ready to learn to play tennis—batting the ball around the court, chasing it when you missed your shot, and generally doing a great deal of work with poor results—you would be greatly pleased if the world champion came along and showed you how to improve your game. Under his coaching you might develop into an excellent player. On a tennis court in a certain city playground an excellent coach trained two world champion tennis players, a boy and a girl. There are hundreds of better courts in the United States, and there are perhaps many other boys and girls who have strength, speed, and courage to become champions; yet most players remain unskillful.

The difference between a champion and an ordinary player depends largely upon the methods each uses. If you start doing things wrong and practice wrong habits, you become worse instead of better, and soon are never able to learn to play correctly.

Can you learn to think? There are world champions in thinking, just as there are world champions in tennis. These expert thinkers make our important scientific discoveries. Champion thinkers do not get their names in the headlines often, yet they enjoy their skill more, and attain results more worth while, than do many famous athletes.

In science you are given the opportunity to be coached in the methods of thinking that have produced world champions! To benefit from coaching you must practice patiently, and

Courtesy Douglas Aircraft Co., Inc.

The presence of this crater in a fairly flat plateau raised a problem: "What caused it?" After careful observation, it was concluded that a meteor struck the earth and buried itself in this huge pit.

constantly try out against stronger competition. You will finally gain such skill that doing things right becomes a habit. An unskillful thinker can improve by using the right system.

Every game has its fundamentals. There are six steps in scientific thinking. These steps are finding a problem, gathering information to solve it, developing a hypothesis [hī·pŏth′ ė·sĭs], testing the hypothesis by experiment, drawing a conclusion, and testing the conclusion.

Just as a person cannot be anything but a loser in sports without skill in all the fundamentals, neither can he be anything but an unskillful thinker if he does not master these six steps.

What is a problem? A problem is a question which demands an answer. Mere idle curiosity about something is not a problem. The question must be one worthy of our time and effort. It may affect our immediate comfort, as when we try to decide whether to carry a raincoat or not. It may be a question of how to make friends. It may be some question that makes no immediate practical difference to us at all, as when we wonder how far it is to the edge of space.

In order to think clearly, make your problem exact by

stating it in words. You will then know what information you need.

How do we gather information? There are many ways of gathering information. If you wonder about carrying a raincoat, you may ask your mother if she thinks it will rain. Or you may go outside to look at the sky and get the feel of the air. Or you may call up the Weather Bureau or read the weather forecast in the daily paper. If you wish to get along better with people, you may watch others who have social skill, and see what they do that is better than the system you use. You may read the advice in the newspapers. You may ask your home-room adviser to suggest ways to improve your manners, appearance, or poise. If you wish to know about the size of space, you may go to the library and get books to read. You may talk over your ideas with your friends as you sit looking at the stars in the summer sky. You may even make a telescope if you are skillful and ambitious.

How do we form a hypothesis? A hypothesis is sometimes called a scientific guess. It is more than a guess, for guesses are usually formed as the result of a chance observation, and without a serious attempt to solve the problem. A hypothesis is a temporary conclusion—one that will be used or thrown aside, depending on whether it is useful or not.

If you decide to leave the raincoat at home, you have formed a hypothesis that it will not rain. You may decide that you can get along better with people if you smile more readily, try to talk about something in which they are interested, and learn some sport so you can meet more people. You may decide that the distance to the edge of space is equal to the distance light has gone in all the time since the sun started to shine, whenever that time was.

How do we test a hypothesis? Scientists test their hypotheses by setting up experiments in which they can make careful observations of what goes on when they make changes or measure objects or compare them with each other. You, too, must test your conclusions, whether you do it carefully or not.

If you left your raincoat at home and rain poured all day and you came home soaked, you have good evidence on which to form a conclusion. If you try out your new social skills

and find that you make several new friends, you have a way of testing your hypothesis as to why you had fewer friends than you wished to have. If you try to test your ideas about the size of space, you will probably find the problem too difficult to test. You will be stopped without any satisfactory thinking.

How do we form conclusions? Your conclusions result directly from your experiment. If you were soaked, you would readily draw a conclusion that your hypothesis relative to leaving the raincoat at home was wrong and should have been rejected. If you win friends, your conclusion is that smiling, being interested in people, and meeting them makes them interested in you.

Courtesy Bausch & Lomb Optical Co.

Experimentation is not new, for we see here a picture of the scientist Alhazen showing—almost a thousand years ago—that a stick thrust into water appears to be bent. The method of science, based upon understanding of all facts, however, is relatively new.

How do we test the conclusion? Many times a conclusion seems entirely sound and correct, but still is based upon an error. In the case of the rain, there is little doubt that you were wet. Reading about the amount of rainfall in the paper and comparing your experiences with those of your friends would verify your conclusions whether they needed verification or not. Your conclusions regarding making friends might be right; yet it is entirely possible that you made friends because you improved in ways you did not think about.

How do we solve a scientific problem? Scientific thinking is useful in everyday living. It saves much wasted effort and unhappiness resulting from errors. It makes us more open-minded and willing to gain information before we act.

Scientific thinking is not only useful but an absolute necessity in solving problems that require an exact answer. Let

us consider the problem, "How does the weight of oil compare with the weight of water?" Of course it is easy to say, "Oil is lighter."

But to gain evidence, observation is necessary. In lifting a can containing oil, it may seem lighter than a can of the same size containing water. It is also observed that oil floats on water.

To form a hypothesis, we decide that oil in general seems lighter than water. We select one kind of oil to test.

The experiment for determining the answer requires some apparatus. The bottle is weighed. Then it is filled with water. The bottle of water is weighed. The bottle is then emptied, dried, and filled with oil, and weighed. By subtracting the weight of the bottle in each case, you have the weight of the oil and the weight of the water. Here are two of the important factors in experimenting: measurement and comparison.

Forming a temporary conclusion is simple. An exact result is obtained by dividing the weight of the oil by the weight of the water. This number is called the specific gravity of the oil. A number is more exact in meaning than a word.

The conclusion that oil is lighter than water can be verified by repeating the experiment with many kinds of oils. It is always possible that you will find an oil heavier than water. Then your conclusion for each kind of oil would be limited to the kind of oil measured.

When you draw conclusions, be sure that you have the correct cause and effect related to each other. The cause must come first, and must always produce one, and only one, effect. Things that happen together may not even be related to each other. Verify every conclusion. Every cause and every effect must really exist!

Does thinking scientifically pay? Scientific thinking is worth while if you think that civilization, long life, comfort, freedom from disease, food, clothes, movies, the radio, newspapers, and almost every common thing you use are worth while to you. If you do not value these things, nothing can have much value. Scientific thinking has produced every completely correct bit of information you possess, and has made possible the producing of almost everything you own or use.

There is no correct kind of thinking other than scientific thinking. It is occasionally possible to get correct answers by chance. It is also possible to do many things so improbable that you cannot depend upon them. You might throw a baseball into a tomato can 100 feet away and have it stay there. But you do not believe it probable. Even when correct information is gained by chance, nobody knows if it is correct or not, or why it is correct.

If you do your scientific thinking as the result of knowing the rules and planning the steps, you will know when you know. When you do not know, you will know how much you do not know. You can plan with a feeling of confidence.

Exercise. *Complete the following sentences:* A —1— is a question that demands an answer. Before we experiment, we obtain all the —2— we can and form a —3— or working idea. An —4— involves weighing or measuring to obtain exact information. From our experiment we form a —5— which must be —6—. The only correct information we have is that obtained by use of the —7— method. The —8— must come before the —9— and must always produce the same —10—.

Science activity. Perform the experiment described in the problem. Make a balance that will actually weigh accurately. Make weights of small boxes or envelopes loaded with sand or shot. Compare them with the school weights.

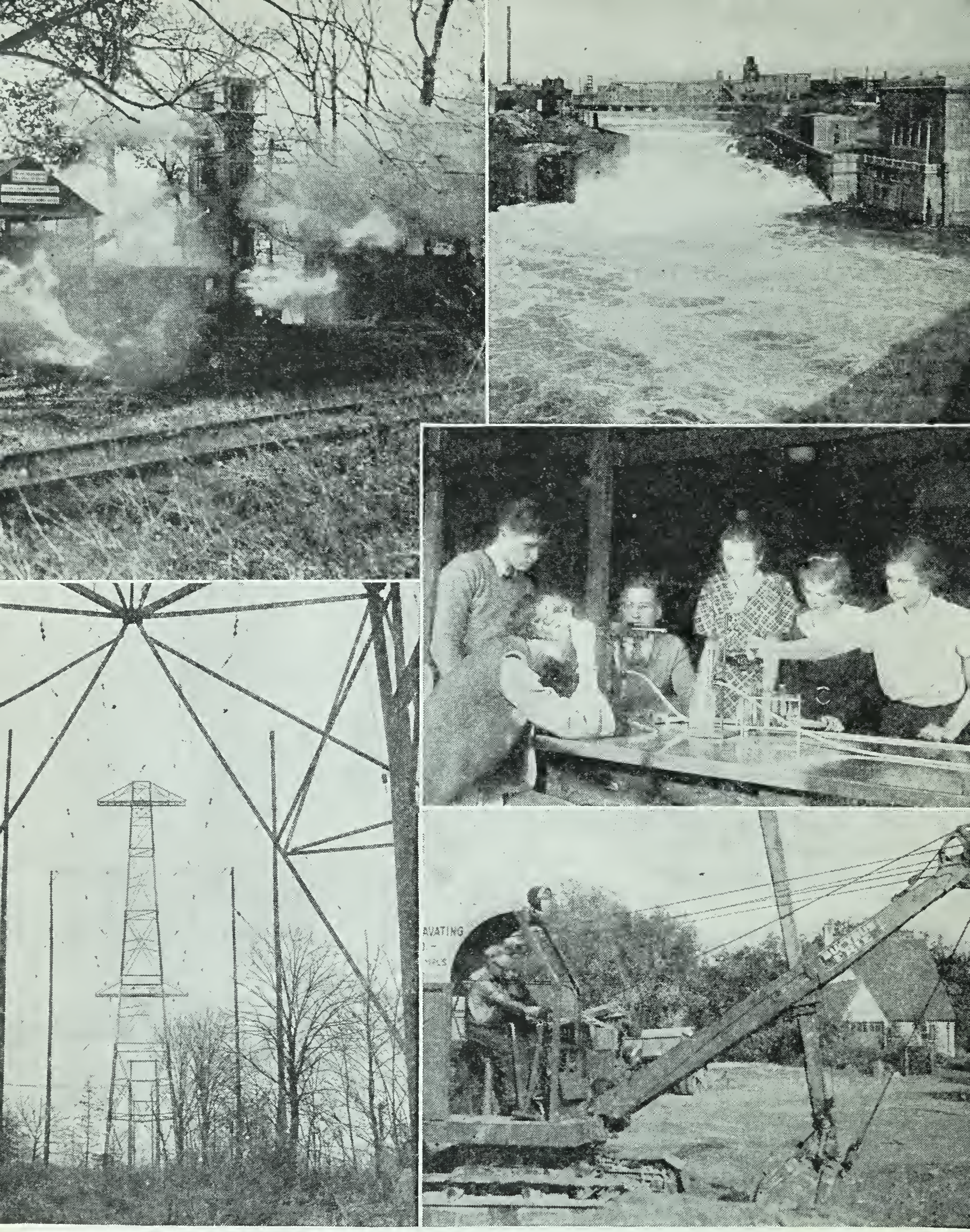
2. How does knowledge develop into science?

When the scientific method of thinking is successfully used in solving a problem, information is obtained. After sufficient testing, the information becomes an established fact — knowledge of which one is certain. When another related problem is solved, more knowledge is gained. As scientific experiments are carried on by many people and under different circumstances, many related facts are developed.

Finally so much information is developed that it begins to overlap, and it is apparent how the ideas are related.

How is science organized knowledge? Until there is knowledge, it is impossible to organize it. But until knowledge is organized, it is not science. Science is the result of two processes: collection of facts and organization of the facts.

There are many ways of organizing knowledge. One branch



Top left, U. S. Bureau of Chemistry and Soils; top right, Spokane Chamber of Commerce; center, Bausch & Lomb Optical Co.; bottom left, R. C. A. Mfg. Co., Inc.; and bottom right, Eugene Rosing photo

Physics covers many subjects. The explosion at the top represents heat, and electricity is produced in the power plant. The radio antenna at the bottom is useful in producing sound. Light is represented by the students using the spectroscope to identify chemical elements. The steam shovel at the bottom represents machines.

of science is called physics—the study of physical changes of matter. Physics is a tremendous field of science—in fact all science is physics. Even life processes, the changes of growth and motion, are physical changes.

Because physics is so broad a science, it is further divided for convenience into studies of machines, heat, light, matter, sound, and electricity. In turn, each of these branches of physics is divided into smaller divisions for the convenience of those who wish to learn a great deal about some particular problem of heat, light, or any other branch of physics.

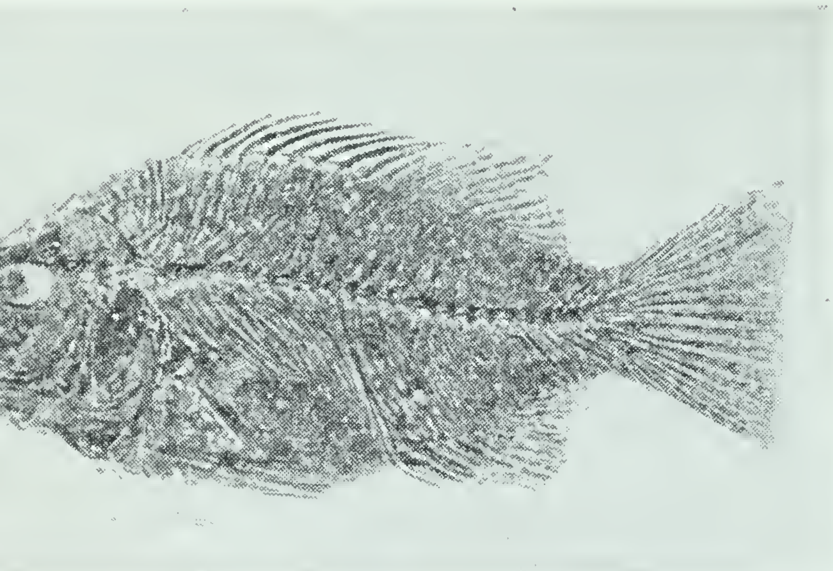
Another great field of science is chemistry. Chemistry is the study of the changes which take place in the make-up of matter. Chemistry is divided for convenience into two great fields: inorganic, which deals with those things not containing carbon, and organic, which is the study of carbon and the compounds of carbon. The word organic comes from the word organism, which refers to living things. It once was thought that the study of nonliving and living things was two separate branches of chemistry. It has since been learned that formation of organic compounds is similar to other chemical changes.

Chemistry overlaps physics, and one may study in universities the field of physical chemistry. In fact physics and chemistry are so often involved in the same changes at the same time that they are separated for study only for the sake of convenience.

A third great field of knowledge is biology. The prefix "bio" comes from the Greek word *bios,* meaning life. The two sciences related to biology are botany, the study of plants, and zoology, the study of animals. Each of these sciences is further divided into sciences of classifying living things, of studying their structure, of studying their habits, and many other fields of knowledge.

Biology overlaps chemistry and physics, for all life processes are chemical and physical changes. In advanced science one may study biochemistry, which is the chemistry of living things.

The science of the earth is called geology. Geology is chiefly a study of the crust of the earth and its history. To know the history of the earth, it is necessary to know biology, for



The bones of this fossil fish were found in a ball of dried clay. To understand how the fish was so well preserved and to know what kind of fish it was, requires an understanding of geology and biology.

the age of the rocks is determined in part by the types of fossil animals found in them. The age of rocks is also determined by study of the elements from which they are made, and particularly by study of radium and related chemicals. This study is both physics and chemistry. Study of the movement of the crust of the earth is both geology and physics.

Another great field of science and, in terms of its history, the oldest science is astronomy—the study of all the bodies in space. Astronomy is a branch of physics, for the stars are studied either by observing their motions or by studying their light, both of which are problems of physics.

All sciences finally depend upon mathematics for a means of expressing in an exact way what is learned by observation and experiment. Many of the divisions of science were set up before enough was known to realize how nearly all fields of science are really one field. The divisions of science are kept today because there is too much to study at one time, and because it is convenient to divide science into units small enough that they can be studied.

What is general science? When we study general science, we take whatever scientific knowledge we can find which helps us to explain our surroundings and which helps to solve our problems of daily living. We do not often think of the divisions of science, except as it is easier to get acquainted with part of our environment if we first find out the rules under which it operates. We would be confused if we tried to study living things and electric lights at the same time, although electric lights, properly used, make living things grow better. We study as much as we can understand, then try to relate one part of our environment to another.

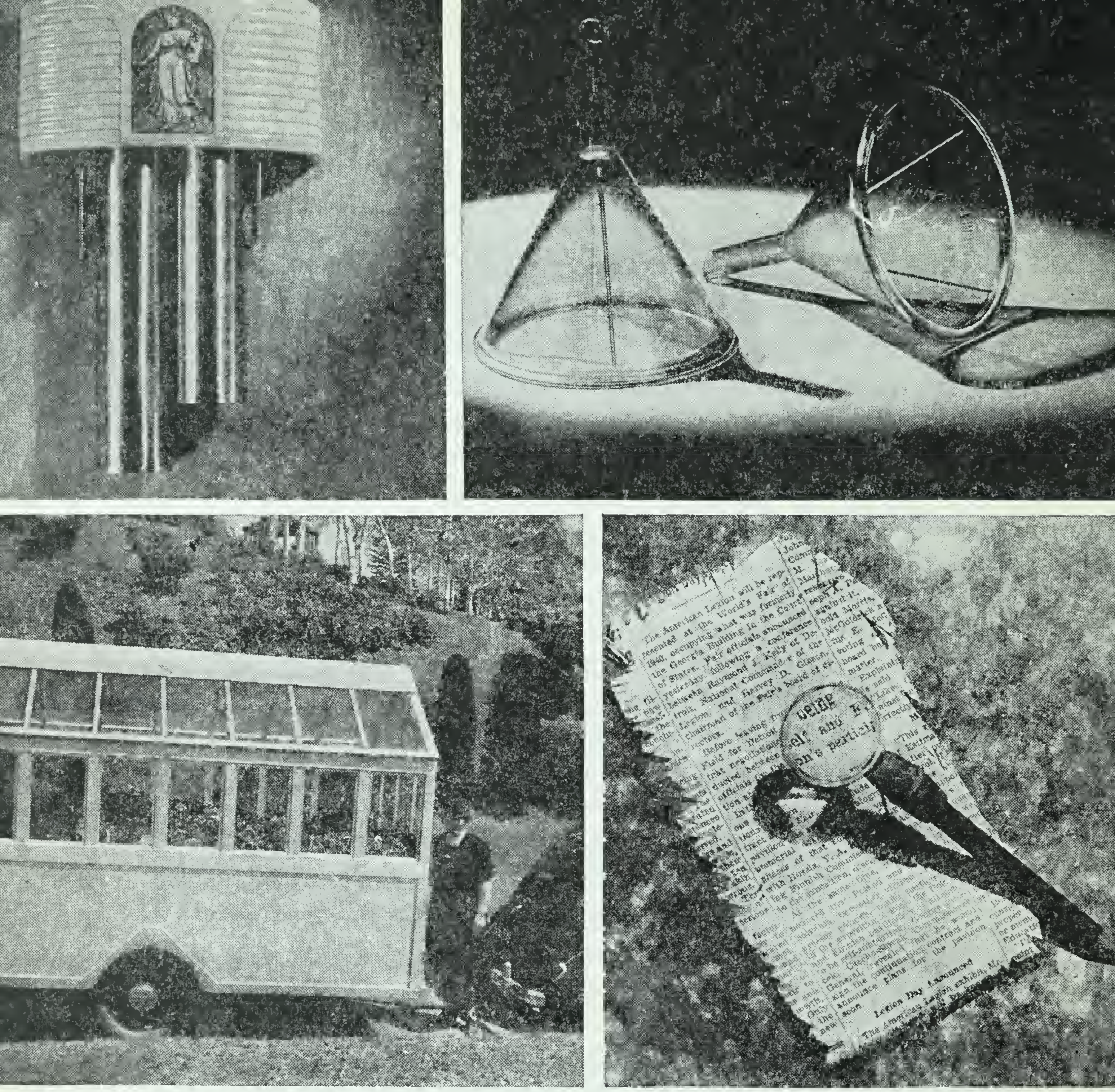
Is scientific knowledge still growing? At times we are inclined to think that there is nothing left in the world worth doing, for all the great discoveries seem to have been made. Such is not the case. The world is full of unsolved problems. Nobody really knows the difference between living and non-living things. Nobody knows just what matter or energy are. There are some diseases that nobody can cure. Nobody knows why we grow old. Nobody knows how the earth was formed. There are so many things to learn that only the shortness of our lives and the limits of our minds can keep us from learning some new thing as long as we wish to study.

Scientific knowledge grows through definite stages. As you studied the six steps in scientific learning, you learned that one of the steps was the formation of a hypothesis. The hypothesis is a working guess. Sometimes knowledge never gets beyond the hypothesis stage, because it is impossible to test it by an experiment. For example, the development of the earth is explained by a hypothesis, because it is impossible to perform an experiment to form an earth, just to see how it is done.

If a hypothesis is tested and a conclusion is formed, the resulting knowledge is called a theory. A theory is based on incompletely developed proof. We have many theories in science. The explanation of how life developed on the earth is a theory, for the origin of simple life has not been proved beyond a reasonable doubt. Yet the testing of the idea by digging for fossils, by study of living things, and by careful reasoning, indicates that our present knowledge is correct.

When a theory has been completely tested and verified by every possible method of which anyone can think, we have developed a law. A law is a statement of known facts. If it truly is a law, there is no doubt of its truth.

One of the most important things you must learn in order to be scientific in your thinking is to understand how completely a given idea is developed. If you state a theory as a law, and later somebody tests it further and finds it wrong, you have been guilty of careless thinking. Even great scientists have been, and probably again will be, mistaken in this way. At one time it was thought that the atom could not be broken up into smaller parts. Scientists were sure that this



Courtesy Monsanto Chemical Co. and Plaskon Co.

Scientific research has given us plastics which are used for such varied objects as doorchimes, funnels, portable greenhouses, and reading glasses. In each case the plastic has some marked advantage over glass.

knowledge was a law—that is, they believed that matter could not under any conditions be destroyed or changed to something else. Today we are much less sure of this idea. We are certain that matter can be changed to energy, and we do not know what becomes of energy under all conditions.

What is science? Science is a body of organized knowledge which has been developed by observation, experiment, and by use of the law of cause and effect in reasoning. Scientific

knowledge is the only accurate and correct knowledge which exists. The degree of correctness of all other knowledge depends upon how nearly scientific were the methods used in developing such knowledge.

Exercise. *Complete the following sentences:* Science is —1— knowledge which has been gained through use of —2—. Scientific thinking is the result of applying the law of —3— and —4—. A —5— is a general statement of known facts; a —6— is an idea or supposition supported by considerable evidence; and a —7— is a scientific guess or working idea. Study of the earth's crust is —8—. Study of living things is —9—. Study of the make-up of matter is —10—. The main divisions of physics deal with —11—, —12—, —13—, —14—, and —15—.

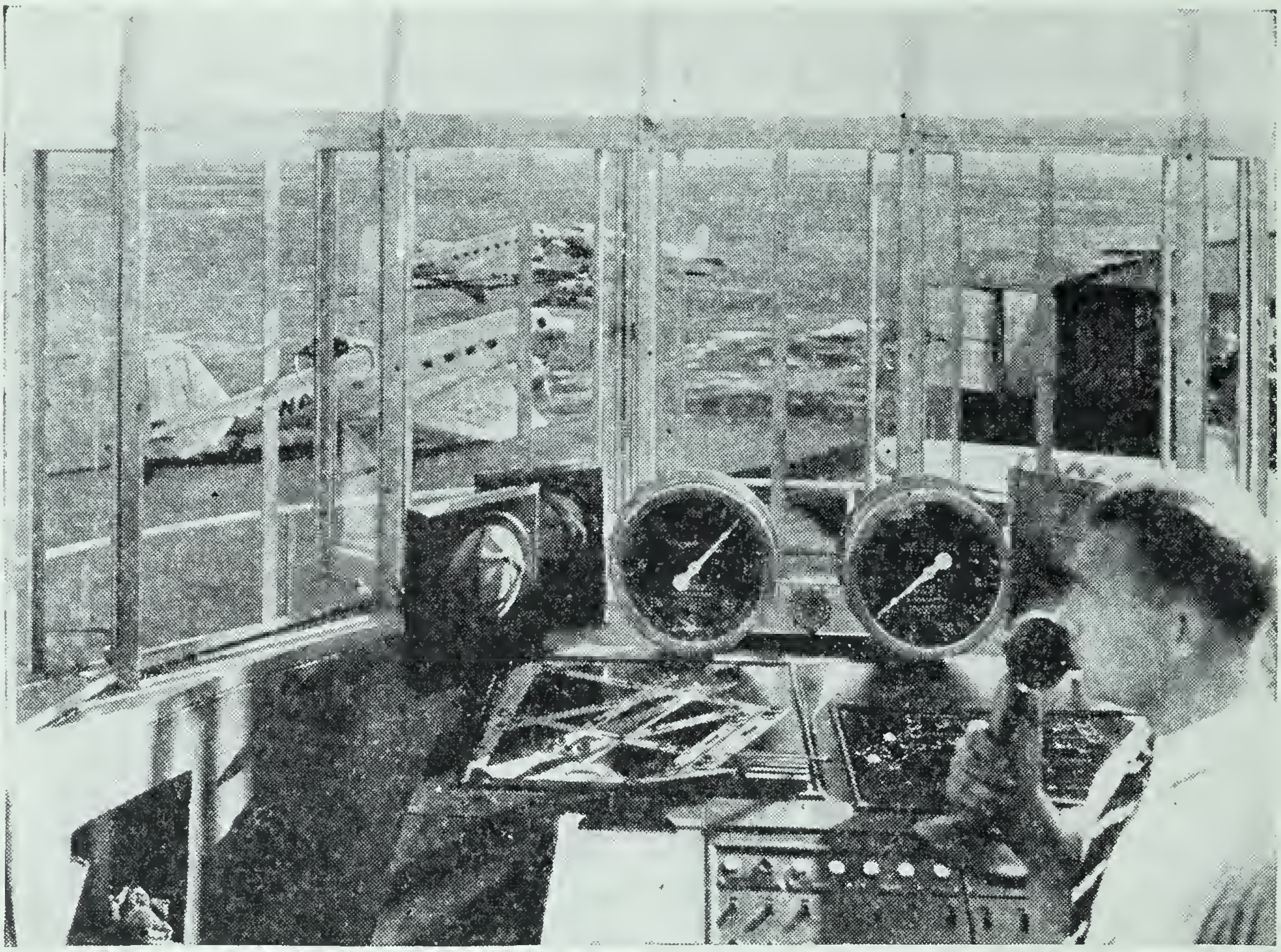
3. Can you profit from studying science?

Although you have studied science, you probably do not yet realize just what personal benefit you have received from your work. Some of these benefits should be immediately apparent to you. You know more about the world in which you live, and understand better the forces of nature to which you are subject. But science can help you with larger problems than this. Four of these are your problem of making a living, your place in the social community, your own personality, and your need to be an intelligent consumer.

Does science help in making a living? Many people depend upon science for their income. All doctors of medicine are scientists. So are some who fit eyeglasses. Dentists must study science four years before they study dentistry. Nurses must study the human body, chemistry, and foods, in addition to their special work in nursing.

Engineers are always trained in science. There are many kinds of engineers. Some draw plans for roads, some direct operations of chemical plants, some operate radio stations, some operate manufacturing plants. Airplanes are designed by engineers.

Industry employs hundreds of scientific specialists for research in producing new goods, and in producing standard goods more economically or efficiently. Many scientists are employed in the U. S. Forest Service; in the national, state, and county agriculture departments; and in the Weather



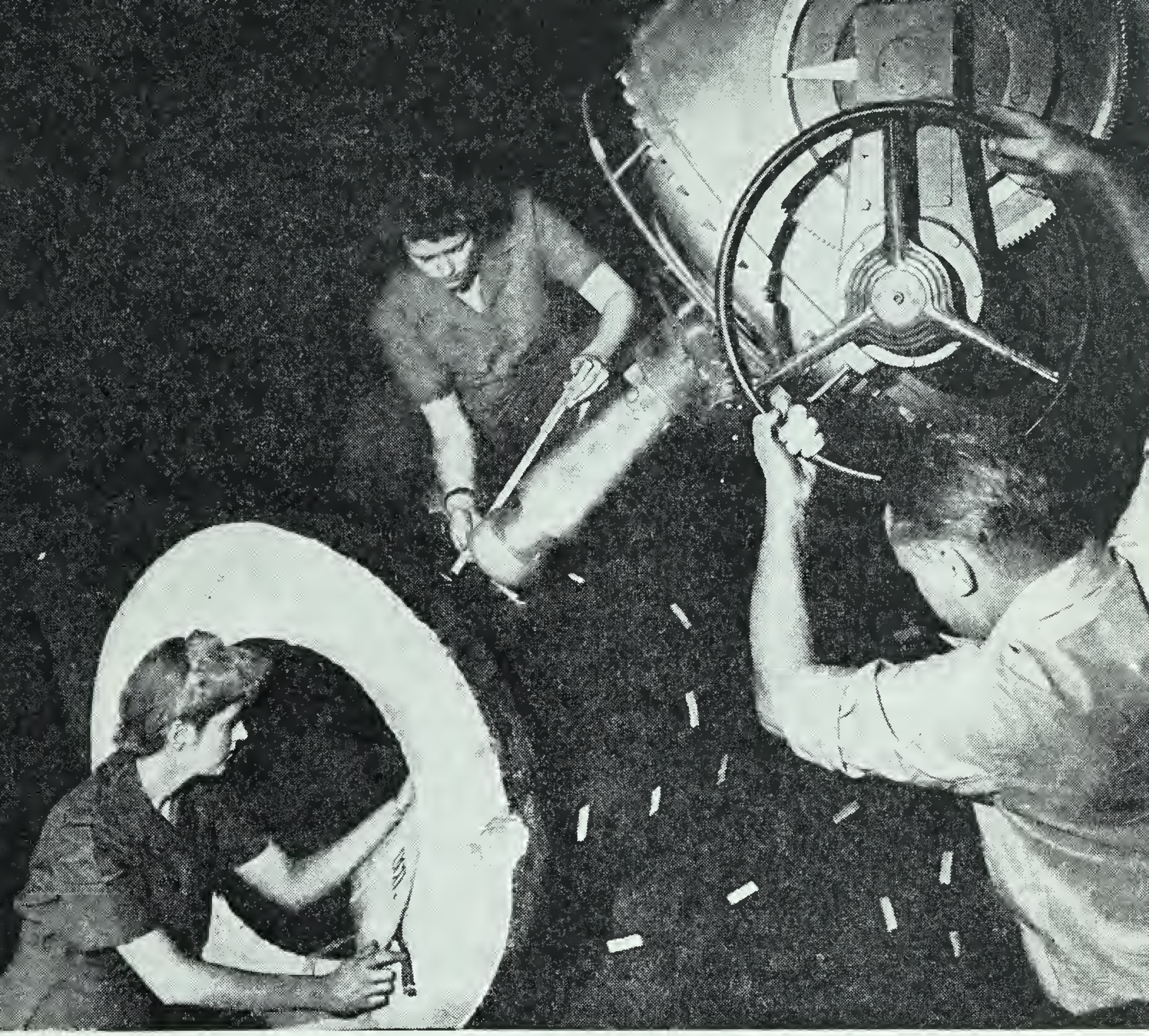
Courtesy Western Electric Company

On the desk of the control tower of the airport are controls for lighting the field, two wind indicators, and three loud-speakers, used to carry on conversations with pilots of the approaching planes.

Bureau. Radio, telephone, and telegraph systems employ a number of scientifically trained men.

In occupations related to scientific work, but not truly scientific in their nature, are actually hundreds of kinds of work. Agriculture, homemaking, cooking, clothing trades, barbering and beauty-parlor work, lumbering and manufacturing offer many kinds of work which are based to some extent upon scientific training. Men who install refrigerators, plumbing, and gas appliances are using science in their work. You can understand better the job for which you are training yourself if you have a good understanding of science.

Does science help improve society? Today there is great need for careful thought and restrained action in the world. Science teaches you to think before you act, whereas many forces are trying to lead you to act without thinking. We are addressed over the radio by men whose only aim is to get us sufficiently excited to do what they want us to do, whether



Courtesy General Electric X-ray Corporation

These people are using a million-volt X-ray unit to find out if there are flaws inside the heavy piece of steel. X rays can pass through heavy metal and other objects through which we cannot see. Since we cannot see inside such materials directly, we must use other aids for observation.

it is to vote for a pension plan or to buy a new kind of shoe polish. Many of the forces which are directing our lives today are governed by ignorant people who do not understand the meaning of their own acts.

You must learn that a majority is always needed for the operation of a democratic form of government, but also that a majority can be wrong. When Galileo stated that the earth revolves about the sun, he was a minority of one. But he was right. At the beginning of any attempt to solve a new problem, the majority is always wrong, for the majority does not have information to use in thinking. We have seen many experiments performed in government in this and other coun-

tries, but they were not called experiments. These experiments were offered as final, perfect solutions for the problems of the moment. A little thinking on our parts may keep us from getting involved in a costly experiment in government which may not work out well. We must solve our problems with our minds and not with our emotions.

Until scientists can have freedom to work everywhere in the world to solve the problems of production, distribution, and use of goods, we will have poverty. Social problems are so complex that nobody has much knowledge for their solution today. It is a mark of a person untrained in science to demand a quick solution and immediate action in solving problems. Such quick solutions are almost always wrong, and such immediate actions ruin the chances of finding a better solution.

Science is useful only when people permit it to be used. If scientists are forced to continue to work only on simple problems like those of physics and chemistry, we cannot hope for much improvement of our social conditions. We must work for change constantly while never changing so fast but that we can go back to what we had in case we make mistakes.

Can science improve your personality? There are still many people in the world today who are superstitious, ignorant, and opposed to learning. You may become one of them unless you obtain a broad background of knowledge. There are people who wear charms and carry good-luck pieces. Some have peculiar beliefs about witches and the evil eye. It is still possible to buy "medicines" to make others like you. You must of course learn that you cannot get something you want by any kind of wishful thinking, either with charms or without them.

You should be able, because of your study of science, to get rid of many of the fears which keep people upset. You need not be afraid that the world is coming to an end when you know that so far it has survived for three billion years. You need not worry about luck, for you know that cause and effect do not leave any place for luck. You will, of course, understand that you may not know all the causes and effects, and that many are not under your control. Yet you know that getting a job or passing a test or scoring a basket in

basketball is not the result of luck. You will learn to take responsibility for your part of the causes which get the effects.

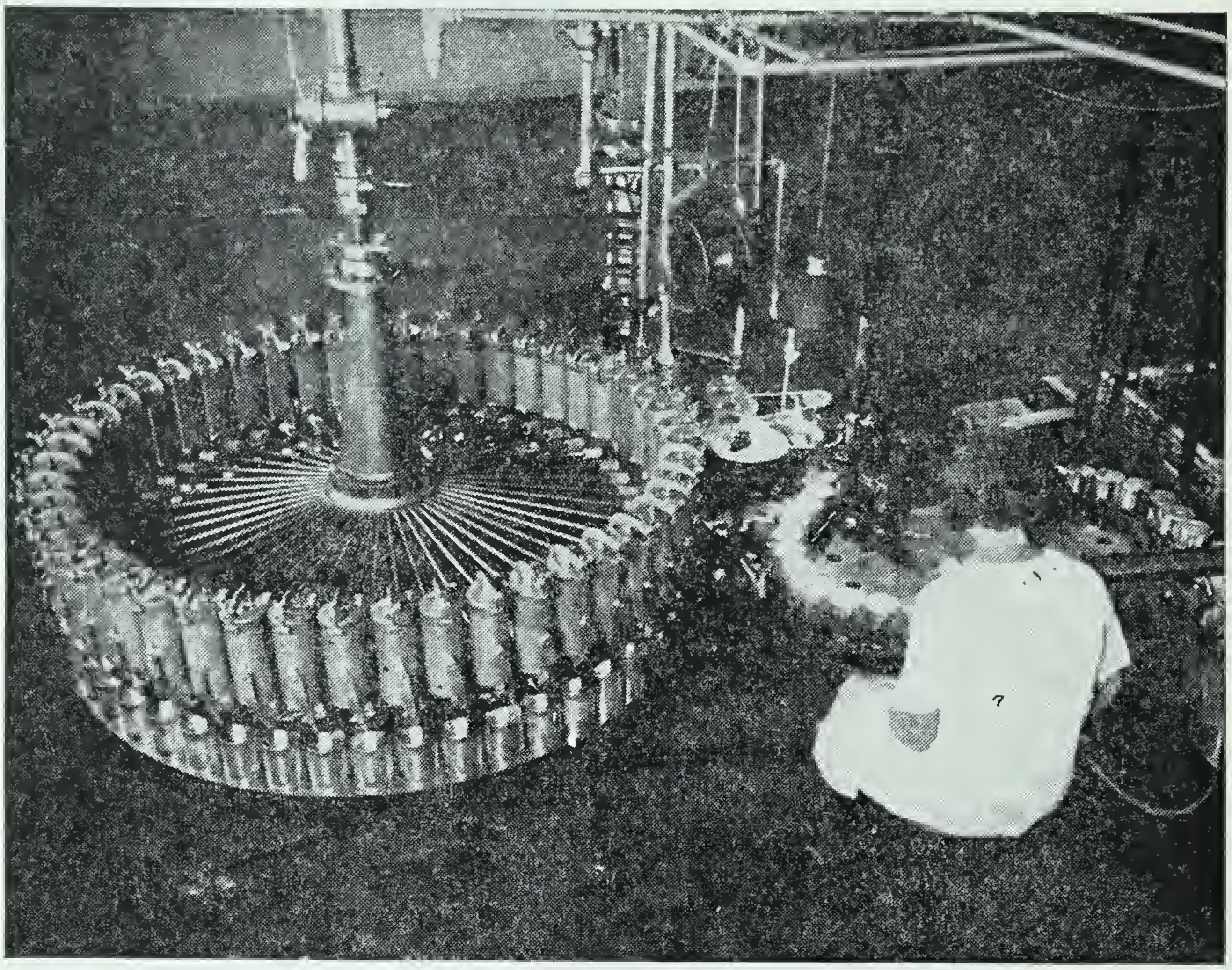
A scientist once said that there are two kinds of people in the world: the soft-minded and the hard-minded. The soft-minded solve their problems by running away from them, by denying that unpleasant things exist, and by trying to escape the consequences of their acts. The hard-minded look upon the world as it is, count carefully the probable causes and effects, face facts, and do not try to run away in daydreams or by blaming fate for their lives. Science should make you hard-minded. It is the healthier mental condition.

Courtesy American Red Cross

Are you reasonable and self-controlled in your behavior, or are you constantly in danger or difficulty because you do stupid things? Have you the show-off habit like this foolish boy?

Are you a wise consumer? Today it is almost as important to be a good consumer as it is to be a good producer. The world is offering such a variety of things to buy that we must obtain a sensible point of view toward wanting the fruits of scientific production. We probably do not spend more than half our money satisfying actual needs. The other half we spend on things that somehow seem desirable to us without their satisfying us at all. Many children chew gum because it satisfies temporarily a nervous need for moving the mouth, or because they have learned to like the flavor. Yet nobody needs gum. We frequently go to the movies when we may really need to play or to increase our circle of friends.

Many of the things which you will learn about in this book —the radio, new kinds of lamps, the automobile, vacuum cleaners, foods, and many others—may vary greatly in their value to you. If you consider your own needs instead of the appeals made by advertisers or the show your friends make of new equipment, you may spend your money more wisely than if you do not know the value of these devices.



Courtesy Irradiated Evaporated Milk Institute

In order to be an intelligent consumer, we should know how various products are made. Here cans are being filled with evaporated milk which has been radiated with ultraviolet rays. What does this mean?

You owe it to yourself to learn all you can in science about the operation, construction, and principles of the many devices which are available for your use. You should then decide which ones you want most. Nobody can afford them all, for even if he has the money to buy them, he still has not the time to use them.

Can science give a feeling of personal satisfaction? Related to the development of a stable personality is the need for a feeling of accomplishment. If you collect stamps or bake a cake or paint a fence, you have done something worth while. All these satisfactions are temporary, for their value soon is either lost or changed.

Many of the facts you learn in science, too, may change. But underneath the changing facts you have learned and will learn are certain principles. These never change. You have something worth while to which you can tie your personal experiences. Science gives you a feeling that you belong to

the world because you understand it. You can look into the sky and know what weather the clouds may bring. You can see in the stars the evidence of the vastness of space. You can look at a machine and know that man's skill brought it into existence. One of the best feelings in the world is the feeling that you are a part of your environment.

Exercise. *Make a table by ruling your paper into eight columns. Head the columns as follows:* HEAT, MACHINES, ELECTRICITY, PLANTS, ANIMALS, HUMAN BODY, FOODS, WEATHER. *In each column write the names of occupations in which the knowledge indicated in the headings is especially important. An occupation may be written into more than one column.*

4. Are you superstitious?

It is difficult for any of us to be certain that we are free from superstition. Many superstitions are so widely accepted that we do not even think of them as being anything but facts. Other superstitions are so appealing to us that we want to believe them even if we know that they are not true.

Are some superstitions based upon fears? People in general are afraid of those things they do not understand. The things that today are explained clearly and sensibly by scientific experiment were deep mysteries in ancient times. Many matters relating to changes in seasons, weather, sickness, death, and ordinary events seemed to primitive people to be controlled by some perverse fate. The custom grew of trying to bribe the fates or gods or devils, which were believed to be in charge of natural events, to be favorable. We still have a tendency to try to win good fortune by doing silly things which are in no way related to the cause of good fortune.

We cannot blame the ancient peoples too much for their fears. Before the invention of the microscope, bacteria were just as hard to imagine as were devils—both were invisible. The belief that evil spirits caused disease seemed reasonable. Until a definite cause-and-effect relation was proved to exist between bacteria and disease, there were no explanations much better than belief in evil spirits.

Do superstitions result from faulty observation? Many of our superstitions are based upon careless or inadequate

observation. The belief that the changing moon causes the weather to change is such a belief. There is also a tendency to draw evidence from too few cases. Thus if one sees a person who is pale, physically weak, and very bright, he concludes that these traits always go together. This is not the case, of course.

A type of faulty observation causes the naming of things that do not exist. There are many purely imaginary animals described in great detail—sea monsters, combination lions and eagles, and so forth—that never existed except in the mind of a careless or imaginative observer. Imaginary relationships are named just as are imaginary objects. Mind reading is believed to be such an imaginary relationship. For example, some women claim to have special intuition not possessed by men.

Do superstitions result from confusion of cause and effect? Many superstitions are directly the result of confusion of cause and effect. Two things that happen about the same time may be cause and effect, or both may be effects of the same cause, or they may be entirely unrelated.

Most of the superstitions about luck result from confusion of cause-and-effect relationships. If a baseball player wears a certain shirt when a hitting streak starts, it is not because of the shirt that the hitting continues. Yet many players will wear the same shirt until the hitting streak is broken. A rabbit's foot can't change your science test, but some pupil who takes the test in this problem will have a rabbit's foot in his pocket to bring him luck! In this test, such beliefs will bring failure.

How does superstition result from wishful thinking? Some people wish for a thing so much that they believe it to be true. Most people feel that there should be some way of making things even, so that a beautiful girl should be dumb, a slow worker exceptionally skillful, and a poor person unusually honest. Unfortunately such relationships are less likely to exist than are the opposites. Good things tend to go together.

Fortunetelling is dependent upon both a fear of the future and upon wishful thinking. When a person goes to a fortuneteller, it is to hear some news which he wishes to come true.

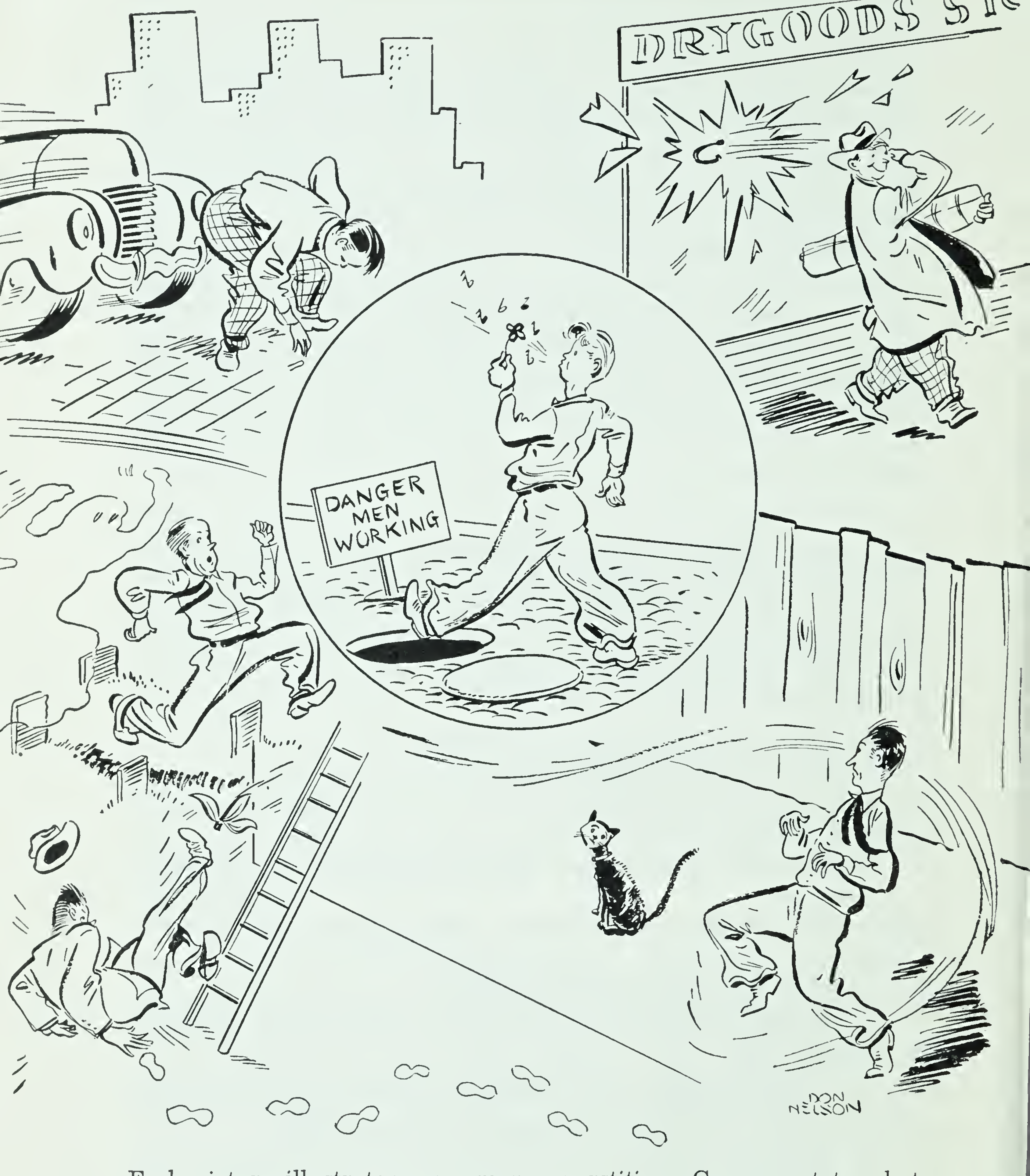
A skillful fortuneteller quickly learns what the person wants to hear, and tells it to him.

Most of our wishful thinking is designed to deceive ourselves, however. How many times have you imagined that some other person is deeply interested in you, only to find that such interest has existed only in your own imagination? How often have you decided that you were going to receive a certain gift, when in fact the gift you did receive was not at all what you expected?

Whenever many people do wishful thinking about common desires, a superstition is likely to develop. Such a saying as "It is an ill wind that blows no good" is an example. This sentence is really quite meaningless unless you consider it either as a plain statement of fact or as a wish. Most people use the saying to indicate the common hope for some good even in misfortune.

Exercise. *Make a table by ruling your paper into five columns. Head the columns as follows:* TRUE, FEARS, FAULTY OBSERVATION, CAUSE AND EFFECT CONFUSED, NONE OF THESE. *Classify the following statements by writing the numbers before the statement under the heading which best explains which are true, or why the false statements are superstitions.*

1. Soot on snow makes it melt faster.
2. In the spring toads seek water.
3. In planting vegetables it is important to plant them at the right time of the moon.
4. When salt is spilled at breakfast, plans for the day should be changed.
5. It is foolish to walk under a ladder, for one will have bad luck.
6. Frost forms on still, cold nights.
7. Rubbing warts with a potato will cure them, if the potato is thrown away.
8. Gypsies can tell fortunes better than other people.
9. Ghosts of those who have been murdered are more likely to return than are ghosts of those who die naturally.
10. Improper food will stunt the growth of children.
11. A winning athlete should use the same equipment to keep his luck.
12. Everyone needs a spring tonic to thin the blood.



Each picture illustrates a common superstition. Can you state what the superstition is, and why it is an unfounded belief?

13. You are more likely to get this wrong because of its number.
14. Winter weather can be forecast by the bark of trees and the fur of animals.
15. The ouija board often tells true events before they happen.
16. A willow stick, if properly held, tells where there is water underground.
17. People who rise early are more likely to become rich.
18. A birthmark is caused by the mother's receiving a shock before the child is born.
19. Vegetables are necessary for proper diet.
20. Finding a four-leaf clover or horseshoe will bring luck.
21. It is more serious to break a mirror than a valuable dish.
22. Lightning never strikes twice in the same place.
23. No one can escape the curse of a dying person.
24. Very young children who are very bright seldom amount to much.
25. People generally die at about the same age their parents die.
26. A slow worker almost always does things better than a fast worker.
27. Boils are a good sign because they purify the blood.
28. A person's character shows itself in his handwriting.
29. When the Big Dipper is right side up, the weather will be dry.
30. Dishonesty shows itself in a person's eyes.
31. Genius is a form of insanity.
32. Fat people usually eat too much.
33. It is proved that people can know by mental telepathy what is happening at a distance.
34. Almost all intelligent people are physically weaker than the average.
35. The arrangement of the stars and planets when one is born determines his fate.

A Review of the Unit

The scientific method of thinking develops through six stages. A problem arises. A search for information follows. A temporary conclusion or hypothesis is formed. The hypothesis is tested by controlled observation, by experiment, and by measurement. A conclusion is formed. The conclusion is tested in as many ways as possible.

A conclusion is called a theory until it is definitely proved. Then a general statement of known facts is expressed as a law.

Science is defined as organized knowledge. The law of cause and effect is used in organizing knowledge.

An exercise in thinking

Write the numbers from 1 to 25 on a piece of paper or in your notebook. Each sentence in the first group below is a principle. Each sentence in the second group is an idea related in some way to one or more of the principles. Find the principle to which each sentence in the second list is related. Then after the number on your paper write the letter before the one related principle which best matches the related idea. You may turn back to the text for information if you wish.

List of principles

A. Everything that happens has some cause to produce each effect.

B. The best way to discover facts is by experiment.

C. A hypothesis is a scientific guess.

D. A theory is a supposition supported by considerable evidence.

E. A law is a general statement of known facts.

F. A superstition is a general belief which violates the law of cause and effect or is based upon fear or faulty observation.

G. Repeated testing of ideas is necessary to establish their truth.

H. A name does not necessarily stand for anything that really exists.

List of related ideas

1. The earth was probably formed from material from the sun.
2. A new boy in school made a good class president, so a new boy should always be class president.
3. In spite of the fact that she had not been exposed, Mary had measles.
4. Although a dairy claimed to sell extra-rich milk, its milk tested as average by the Babcock test.
5. Water underground can be located by use of a forked willow stick.
6. A lame man became well as the result of a miracle.
7. The children were excited while waiting for Santa Claus.
8. Every object in the universe is attracted by every other object.

9. What people mean when they say a star is in the heavens is really that it is in outer space.

10. All living things have a common ancestor.

11. The doctors did not find the mind when they operated.

12. Although the magic faucet on a glass plate has no pipes, water runs from it all the time.

13. Thieves are kind because a thief once gave his mother five dollars which he had stolen.

14. Those who say they can read character from handwriting cannot actually do so.

15. One man claims that his experiments show that people can transfer thought for a considerable distance.

16. Although patent medicines are worthless, people claim to be cured by them.

17. All matter is made up of small particles called atoms.

18. Boils are a good sign because they purify the blood.

19. A cup fell from a shelf and broke without any apparent cause.

Courtesy National Bureau of Standards

Observation is greatly aided by use of instruments. This microscope is used to study cloth fibers.

20. Nobody at a party could agree on what was meant by beauty.

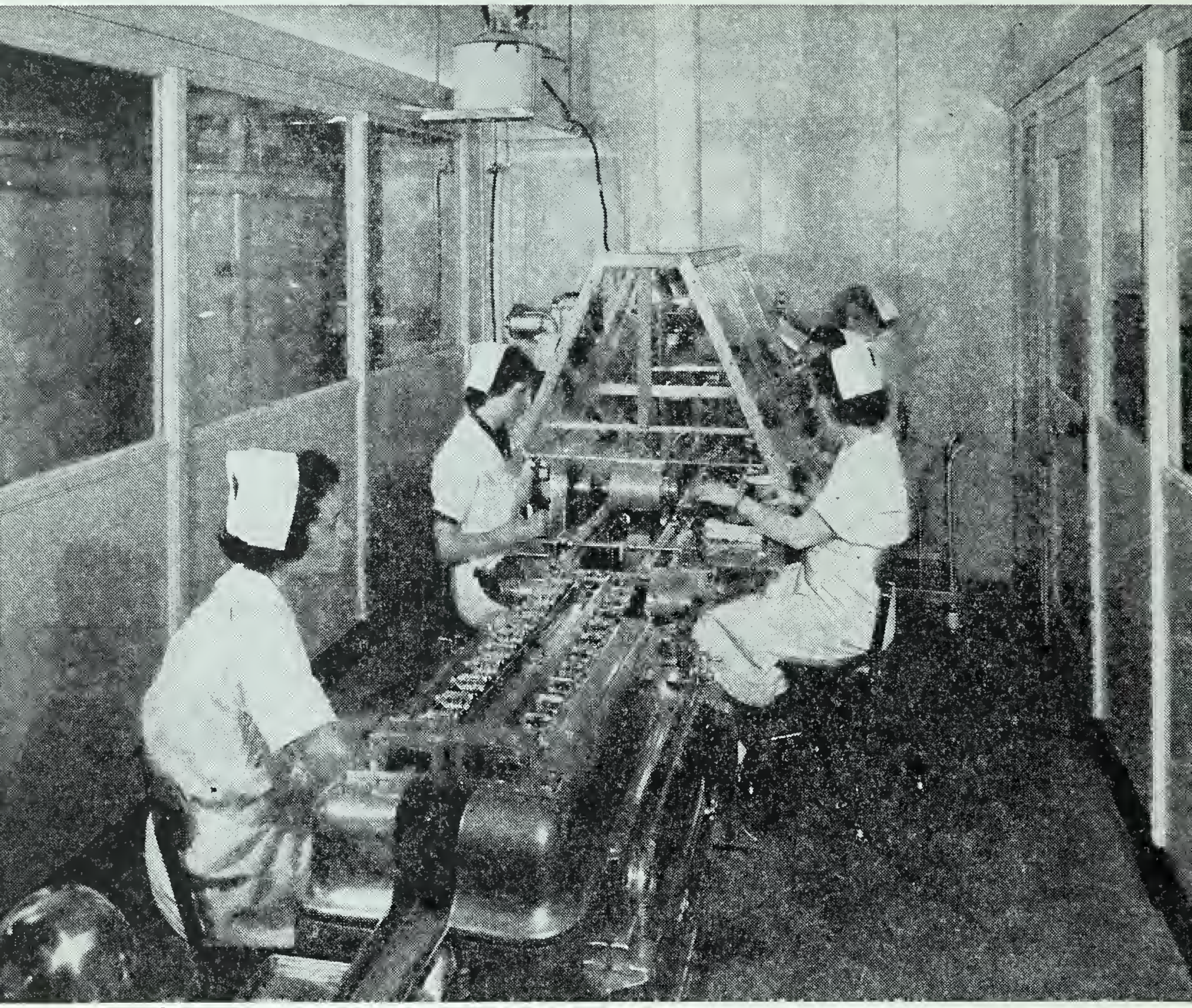
21. A four-leaf clover brings luck.

22. Edison made hundreds of tests to find a satisfactory lamp filament.

23. A birthmark is caused by the mother's receiving a shock before the child is born.

24. The total amount of matter does not change when a fire burns fuel.

25. The so-called "science" of reading character from the shape of the skull was worked out by measuring only a few people's skulls.

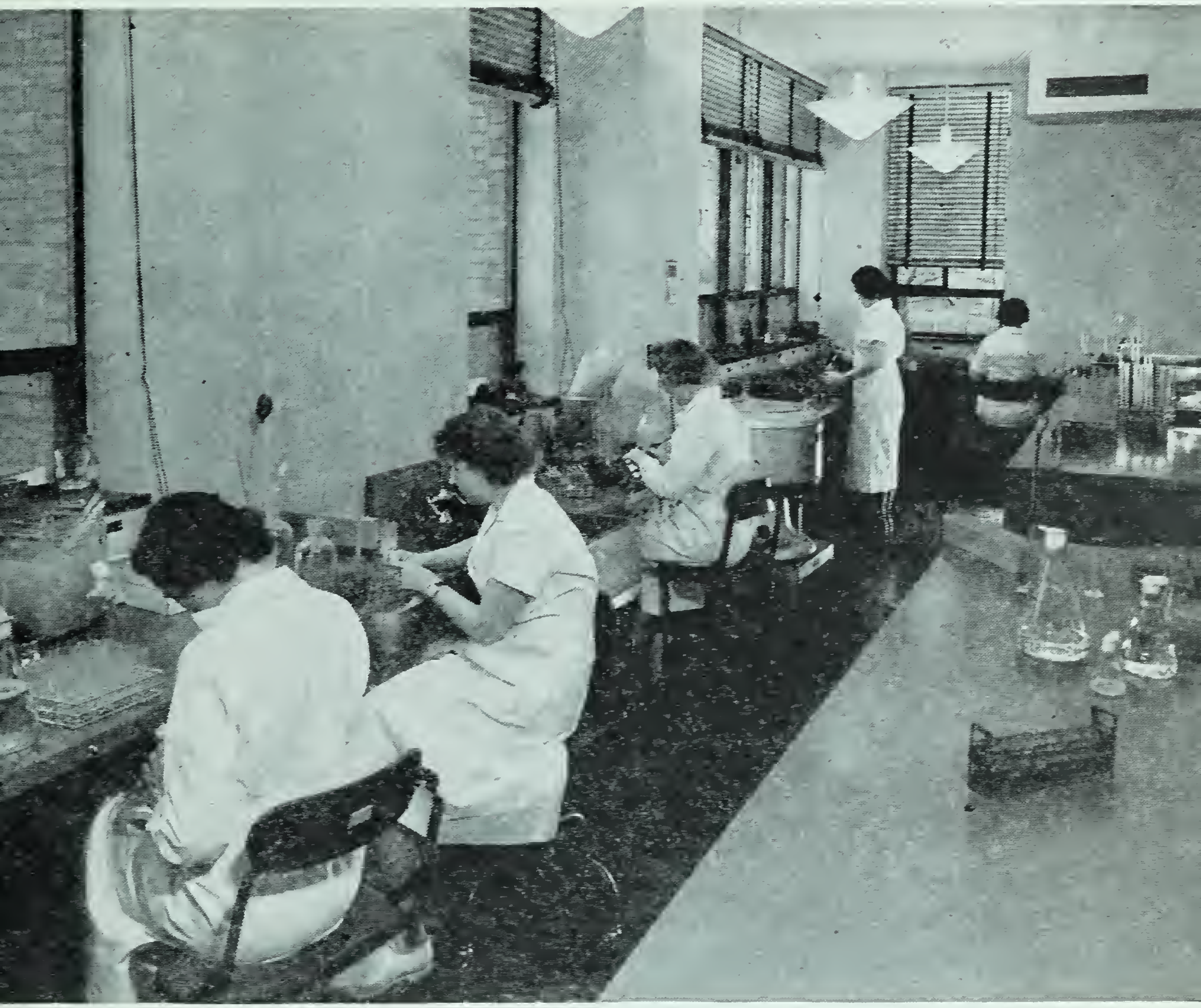


Courtesy Eli Lilly and Company

Most of the work of preparing medicines is performed by automatic machines. These women are operating machines which fill and seal small bottles called vials. Accurate measurement is very important in this work.

Some things to explain

1. Why are people afraid?
2. How has science helped to make you safer?
3. Why does science fail to develop among primitive peoples?
4. Why do scientists fail to receive as much publicity as criminals?
5. Why is it more important for the mother than for the father of children to be trained in science?
6. Why are girls in general less skillful in science than are boys? Do they need to be?



Courtesy University of Minnesota

These women are making blood examinations. Many diseases can be detected by study of blood. Many states maintain laboratories such as this to help diagnose disease. You can see how important the scientific method is in this necessary work.

Some good books to read

Carlisle, N. V. and Rice, C. C., *Your Career in Radio*
Curie, Eve, *Madame Curie*, A Biography
Frank, J. O. and Barlow, G. J., *Mystery Experiments for Science Classes and Science Clubs*
Gray, George W., *The Advancing Front of Science*
MacDougall, C. D., *Hoaxes*
Oliver, Jocelyn O., *Achievement: A Book of Modern Enterprise*

From the Columbia Picture "I Married Adventure"

UNIT TWO

HOW ARE LIVING THINGS ADAPTED FOR SURVIVAL?

ON A June day a man was sitting in his study in a town in New Hampshire. As he sat there, a chimney swift fell into the room through a hole in the chimney. The man picked up the bird and carefully fastened to its leg a tiny aluminum band with a number stamped on it. He then set the bird free.

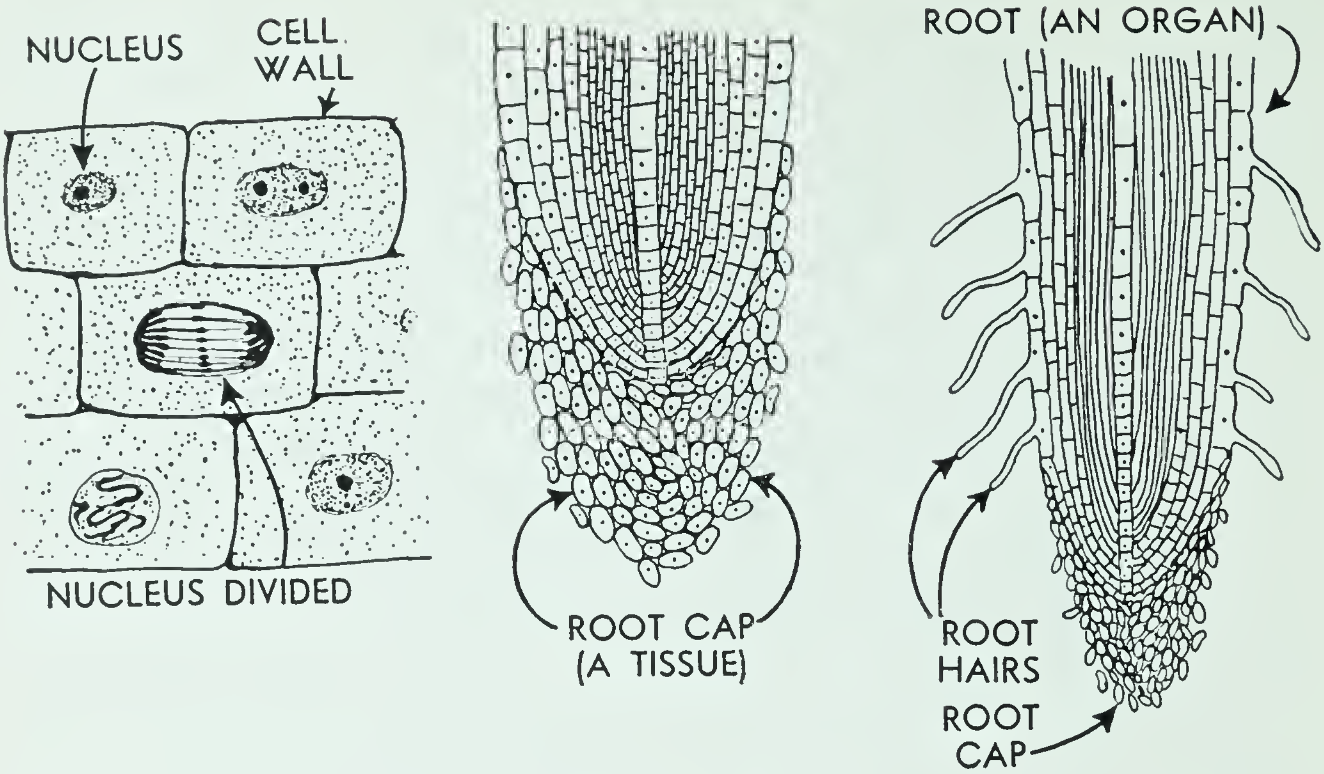
A year later as he was sitting in the same room, a swift again fell down the chimney. He picked up the bird and discovered to his surprise that it was the same bird that he had banded the year before. This bird had traveled to its winter home in South America and had returned after its long journey to the exact spot where it had made its home the year before.

The migration of birds is but one of the many types of adaptations of living things which help them to survive. The problems of survival are complex and difficult. Animals must not only eat, but must escape being eaten. For large animals such as lions this is not as difficult a problem as it is for smaller animals such as rabbits and grasshoppers.

Animals must produce their young and care for them in order that the race or species can survive, and at the same time must protect themselves. Some animals will die fighting for their young, while others will leave the young uncared for to defend themselves. Some birds make beautiful nests, while others lay their eggs on bare rocks. The oriole nest is a down-lined, deep basket. The nighthawk nest is a depression in the pebbles of a rocky hillside. Yet each of these birds manages to rear its young in spite of difference in methods.

Every living thing must find its place in the environment for which it is adapted. For most organisms this is not an easy task, for there are so many living things that they must constantly compete for food, living space, and other needed things to enable them to live.

These problems of survival are but a few that living things must meet. Can you name a dozen animals that are extinct today because they did not solve the problems of survival? Can you tell why they became extinct, while smaller and weaker animals were able to survive? Can you look at your own hands and see how they help you to survive? What would you do if you had paws instead?



All life processes take place in the cells. The cells are in various stages of division and growth (*left*). The root cap (*center*) is a tissue made up of cells. The entire root, including all its parts, is an organ.

1. What is life?

Most of us do not have much experience with plants and animals, nor do we have means of studying living things too small to see with our unaided eyes. As a result we are likely to think of life only in connection with people, the large, four-footed animals, the fishes and birds, a few reptiles, and perhaps a few insects. We find that our experience with plants is confined almost entirely to a few common seed plants.

Yet no matter how limited our observations may be, we note immediately the difference between living and nonliving things. In living things certain processes go on that do not take place in nonliving things. These processes taken together make up the complex process called life.

Life is obviously a process involving use of energy. Yet releasing this energy does not seem to reduce the size of the living organism, as a fire reduces the fuel on which it feeds. Nor do life processes come to an end unless energy is supplied from an outside source, as water ceases to boil when removed from the fire. Life is a process that continues of itself under certain favorable conditions.

What is the stuff of life? If you could add to your obser-

vation of common animals hundreds of thousands of observations of every imaginable living thing, you would have little need for changing your basic understanding of what life is. It is a series of changes that go on in a watery, jelly-like, fibrous chemical substance called protoplasm [prō′tō̇·plăz’m]. For protoplasm is the stuff of life, whether it is found in cabbages or kings.

The simplest living things are mere droplets of protoplasm which seem barely thick enough to cling together in the water in which they live.

While protoplasm exists in very primitive forms, it usually is organized into cells, tissues, and organs, each adapted to perform specialized functions.

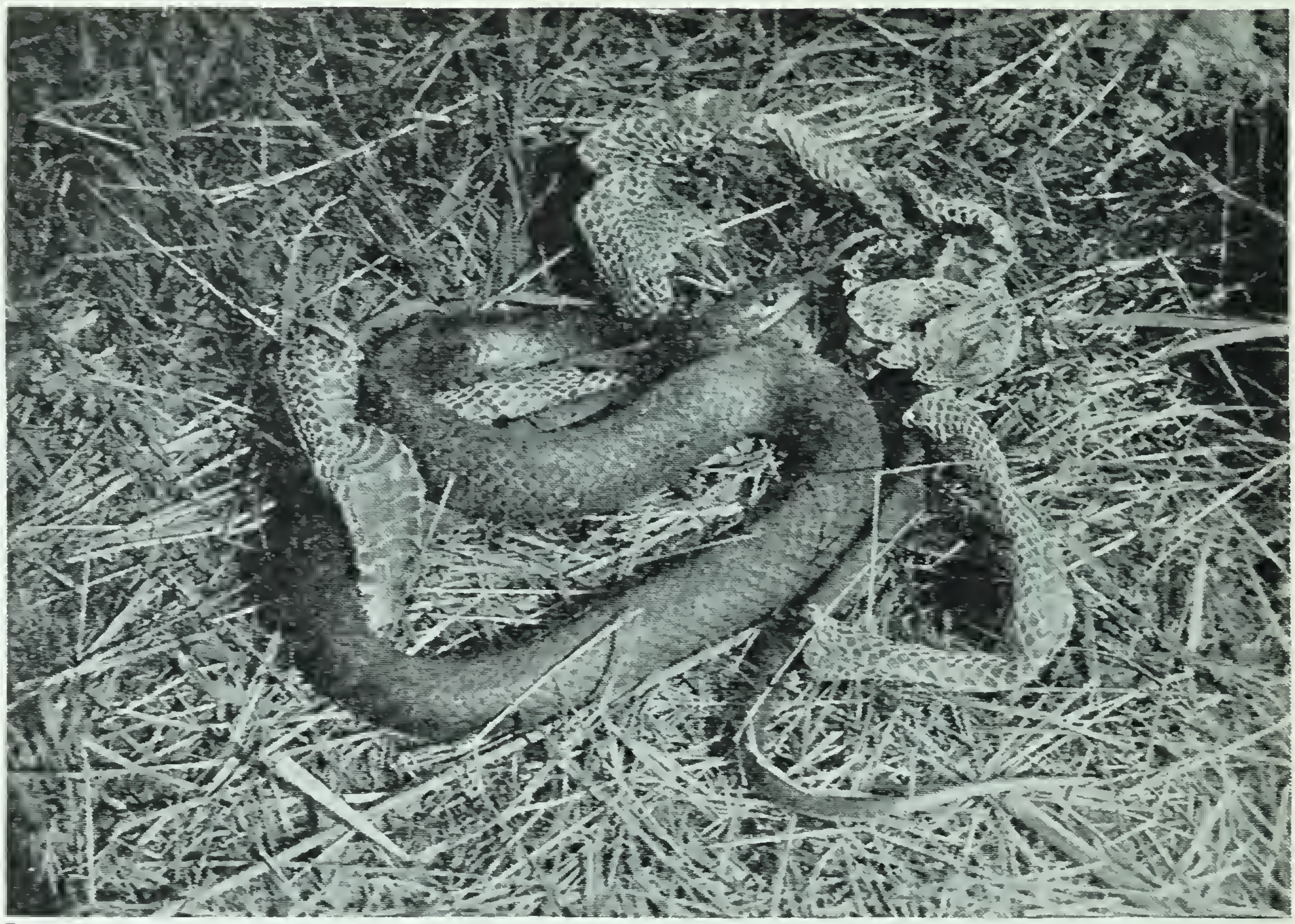
Of what parts are all complex organisms composed? A real understanding of life processes could hardly have developed without the microscope, for the basic building block of complex organisms is the microscopic cell. Cells were discovered nearly 300 years ago (in 1665) by Robert Hooke. But it was not until about 100 years ago that it was recognized that all living things are made of cells.

A cell usually consists of three or more parts. Around the outside there is usually a cell wall, which may be made of one of several materials. Some microscopic sea plants, or diatoms, make cell walls of lime and other rocklike materials. The cell walls of woody plants are made of cellulose, a material from which cellophane is made. Other cells may have walls of materials less familiar than these.

Inside the cell is the protoplasm, which constantly streams about. A central part of the cell is called the nucleus [nū′klē̇·ŭs]. It is thicker in appearance than the other protoplasm, and seems to be the point from which growth and cell division begin.

In any animal containing more than one cell we are likely to find groups of cells similar to each other in appearance and function. These cell groups are called tissues. The lining of the mouth, the material of bark, and the groups of muscle fibers which permit animals to move are all tissues. Each tissue has some special function to perform in carrying on the life processes of the organism.

Groups of tissues which work together are called organs.



L. W. Brownell photo

Many animals change as they grow. This snake has grown a new skin beneath the old one and has shed the old skin.

Roots, leaves, eyes, claws, feathers, stings, and stomachs are organs.

What activities are necessary for life to exist? You already know that there are many functions necessary to make life possible. Among these are the ability to get food and air, the ability to move, and the ability to adapt to the environment. These life functions are closely tied up with certain properties or abilities of protoplasm.

The whole process of using food and releasing energy from it within the organism is metabolism [mĕ·tăb′o·lĭz'm]. Metabolism consists of two different types of activity. One of these is a building or constructive process; the other is a tearing down or destructive process. The constructive process is commonly carried on by plants when they make food, and is carried on to some extent in the bodies of animals, as when cows produce milk. The constructive process also takes place in the cells where new protoplasm is built.

The destructive type of metabolism releases energy. This ability to release energy from food is common to all living

things. Bacteria causing decay of an apple, a plant turning its leaves to follow the sun, and a tiger following its prey through the jungle are all using energy. The bacteria cannot make their own food, but instead absorb and use up the foods on which they grow. In the process they release heat, carbon dioxide, and water. They may also release other materials, depending upon the nature of the food they are using for their growth and activities.

The plant turning to follow the sun uses energy as truly as does an animal, and as a result also releases heat, carbon dioxide, and water from the food stored in its stem and leaves. The tiger requires a much more complex type of food than do the bacteria and plants, and as a result of using its food releases energy in more complex ways and produces more complex wastes. Yet from the body of the tiger heat is released and carbon dioxide and water are given off, as well as more complex wastes containing minerals and proteins (chemicals containing nitrogen).

A second property of protoplasm is irritability—the ability to respond to a stimulus. The stimulus in the case of the plant is sunlight, and the response is a turning movement. The stimulus of the creeping tiger is hunger from within, and a complex combination of sights, sounds, and odors that seem to promise food. Every large muscle cell of the tiger's body

Courtesy U. S. Bureau of Animal Industry

These pups are busy taking in food in order to change it to protoplasm. Without food they could not grow up to become big dogs.

responds to direction or stimulus of the nervous system to make possible the quiet, powerful movements necessary to follow a wild deer through dense thickets.

A third property of protoplasm is its ability to move. You know already that protoplasm constantly streams and flows within the cell, and that most living animals can move about to some extent. These movements, motion and locomotion, are essential for continued life.

A fourth property of protoplasm is growth. This process is closely related to metabolism, for until the building process provides sufficient material to increase the size of the organism growth is impossible. You have already learned how many living things grow—how the chick hatches from the egg, how the fly maggot changes from a wormlike animal into a fly. Growth results from an increase in the amount of protoplasm within an organism, and from a reorganization of the protoplasm to form new cells and tissues. Sometimes entire new organs are produced, as is the case when the fly develops wings in its pupa stage.

A fifth life process of protoplasm is the ability to reproduce. In the beginning stages of reproduction, living things are amazingly similar. For no matter how large or small an organism may eventually be, all start from the growth and division of a single cell. In the case of bacteria the cell divides into two bacteria, and reproduction is complete when the cells carry on their life processes separately. In the case of a higher plant or animal—a carrot or a sparrow—the division of the cell starts a most complex series of developments, which finally produces a large organism made up of perhaps billions of cells all working together.

Exercise. *Complete the following sentences:* —1— is a series of changes that take place in a substance called —2—. The simplest living things are composed of one —3—. In more complex organisms the cells work together to form —4— and —5—. —6— is the process of building up and destroying protoplasm. Wastes formed by the destructive process almost always include —7—, —8—, and —9—. —10— is the ability of protoplasm to respond to a stimulus. Increase in size or change in organization of protoplasm is —11—. All life starts from one —12—. The central part of the cell is the —13—.

2. What characteristic of life makes it able to continue?

This brown bear, like all bears, hibernates in the winter. It is adapted to live in forest regions.

It would seem that in the great variety of soils, climates, and moisture conditions which are found on the earth, some places would be so poorly adapted for life that no living things could possibly survive. Yet in desert places we find the mesquite, a low shrub, slowly working its roots as far as 50 feet through the parched soil for a tiny trickle of life-giving water. On the bare rocks of a mountain, where it would seem that no life could exist, we find growing a dry, scalelike plant—a lichen [lī′kĕn].

In the frozen wastes, a red tint on the snow indicates the presence of algae—another simple plant. Even the ocean is filled with countless millions of floating organisms, some widely scattered and others tangled so close together that they actually retard the movement of ships. To live in all these different surroundings and to withstand the different conditions calls for different types of adaptations.

What is adaptation? Adaptations are the structures and types of behavior which enable an organism to continue to live under certain conditions. Some living things perish because they are not able to adapt themselves to a changing environment, while those that can adapt themselves survive.

The environment includes all those things and forces in the midst of which an organism lives. Some of the factors in the environment are living things—other plants and animals—

L. W. Brownell photo

This ground squirrel is found in rocky regions of the West. It eats grasses and seeds and lives in a burrow.

while other parts are nonliving. The living environment contains factors both helpful and harmful to an organism. All living things depend upon other living things, dead or alive, for food or for materials from which to make food.

How does structure determine how organisms live? Every living thing is adapted to a single, rather limited type of environment. The structure of the organism—the way it is built—determines what this environment is.

The environment of the grizzly bear is the Rocky Mountains. The bear fits into this special environment in many ways. First of all the bear is a mammal, which makes it necessary to live where it can breathe by means of lungs. It is a meat-eating animal, but adds to its diet a limited amount of nuts and wild fruits. The grizzly is specially adapted for digging, for its powerful, slightly curved claws may be three inches in length. The grizzly uses these claws to turn stones over and to tear up rotten logs in search of insects and grubs. The bear digs ground squirrels from their burrows. But the grizzly bear does not always limit his food to these small forms. It is so powerful that it can and does kill large animals, including deer and cattle, by seizing them and breaking their necks. The grizzly bear has a shaggy coat of white-tipped brown or black hairs which enables it to hide among rocks by blending into the background.

In the same environment in which the grizzly bear lives is found the ground squirrel. The ground squirrel also has claws well adapted for digging, and lives in burrows which it digs in loose, rocky soil. Its food consists of seeds, fruits, field crops, and occasionally insects and small animals. Its fur is brown and mottled in color, making it blend into the color of the rocks and dry soil in which it lives.

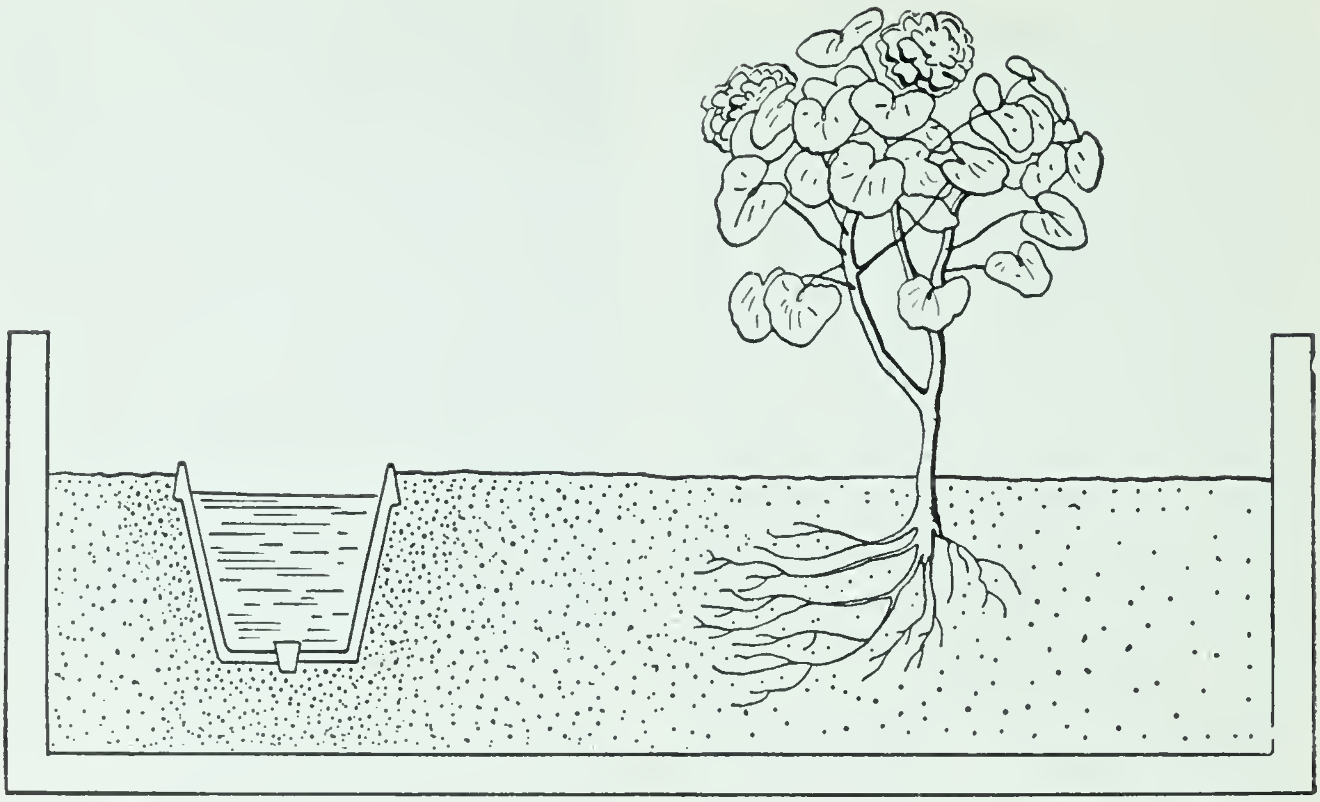
It may appear at first that the ground squirrel and the grizzly have the same environments. In many respects they do. Yet their structures make these environments different in many respects. The grizzly does not need to hide from any enemy except man, while the ground squirrel can protect himself only by staying near enough to his burrow to dive into it when threatened by larger animals—hawks, coyotes, and bears. The grizzly need not consider these factors in the environment, for his great size and strength enable him to travel in safety where he wishes.

The flesh-tearing teeth of the bear and the gnawing teeth of the ground squirrel determine to a large degree the kinds of food each can eat. Their digestive systems differ in size and in the kinds of chemicals they secrete to digest food.

When greatly differing animals are compared, it is still easier to see how structure determines the environment in which the organism lives. A canvasback duck may live on a mountain pond in the region where the bear and ground squirrel live, yet its structure causes it to live an entirely different life. Its webbed feet make it unfit for land, but well fitted for swimming. Its oiled feathers make it able to float on the water. These ducks are so much at home in water that they dive to a depth of several feet to obtain the water plants that root in the bottom of shallow ponds and lakes. The beaks of ducks are broad and scoop-shaped, and are provided with a comblike filter along the edges from which water runs from the food. The nest is always located as near water as is possible, and is hidden among reeds where the gray-brown feathers of the female make concealment possible.

When we compare the structures of warm-blooded animals with those of frogs, snakes, earthworms, oysters, and other cold-blooded animals, these differences become still more apparent.

Plants are as different from each other as are animals. To make a comparison that is easy to see, consider the differences between a water lily and a corn plant. The water lily has a thick, fleshy root from which comparatively few fibrous roots extend, for the struggle to find water and food is not a difficult one. The stems of water lilies are soft and weak. The



The seeking of water by growing roots is a tropism. The water is the stimulus, the increased rate of growth the response.

leaves are broad and flat, and they float on the water rather than being held up by the stem. The flowers are large and showy to attract insects which carry the pollen. The corn plant has a root system of thousands of fibrous roots which extend far into the soil; a hard, tough stem; and leaves which can roll up to reduce loss of moisture. The flowers are small and the pollen is carried by the wind.

How does behavior make animals fit their environments? There are four general types of behavior. The simplest is called a tropism [trō′pĭz′m]. The turning of the sunflower to the sun is such a form of behavior. Tropism in the simple, one-celled animal, the amoeba, is shown when it is touched with a bristle, and its protoplasm flows away to the side opposite the point of stimulus. The seeking of water by plant roots and of light by the leaves are tropisms. The upward growth of stems is also a tropism.

Among higher animals there are three types of behavior: reflex behavior, instinctive behavior, and intelligent behavior. A reflex is usually rather simple in nature, and it is not learned nor is it controlled by thought. The inner workings of the bodies of animals are largely reflexes, for the muscles which control digestion, breathing, getting rid of

wastes, and other life processes do their work without thought or direction. When you drop your cat wrong side up he quickly turns in the air to land on his feet. This is a rather complex type of reflex act.

All the complex acts of most animals are instinctive. Let us see how the instincts of the grizzly, ground squirrel, and duck adapt them for winter. In the Rockies it is too cold for most animals to live, and the snow is too deep for them to find food. The bear and the ground squirrel alike become possessed of great appetites, and eat until they are fat and sluggish. As winter approaches, they each go to a place to hibernate—the bear to a protected cave or hollow under rocks or to the roots of an upturned tree, the squirrel to his burrow. Then gradually they fall into deep sleep, and move as little as possible, until spring finds them restless, lean, and hungry.

The duck joins a flock of other ducks, and practices flying and landing to get into condition after a summer of living afloat on the water. Then on some cold morning the flock takes off and flies south to a warmer region.

You will note that behavior is dependent upon structure. The bear could not possibly fly south, nor could the duck hibernate. The steps that lead to hibernation must come in order, for unless the bear is fat he does not hibernate so early nor stay asleep so long.

In order to grow straight, plants have special structures. Grasses have joints at intervals along the stem. The tropism of growing upward is dependent upon the structure of these joints, for cells grow thicker on one side than on the other until the stem is fairly straight.

Does environment determine adaptations? The kind of adaptations an organism has depends upon two things: its ancestors and its surroundings. No organism has more to develop from than it inherits from its ancestors but, even so, organisms of the same kind differ from each other. Factors in the environment are more favorable to one individual than the other. When deer are chased by wolves, the fastest runners escape, while the slowest are caught. Over a long period of time—usually periods of thousands of years—most living things definitely change to fit their environments. It is only intelligent animals that are capable of making rapid changes,

and even in their case there is a limit to the amount of change that can be made in a short time.

Microscope slide: Algae.

Exercise. *Complete the following sentences:* —1— is a structure or change in an organism fitting it more perfectly to live in its —2—. Claws, wings, and teeth are —3— which help the animal to adapt to its environment. The simplest type of behavior is a —4—. Internal behavior of animals consists mostly of —5— acts. Migration and hibernation are examples of —6—, which are complex acts. Color of animals helps them to —7—. All living things depend upon others for —8—. The canvasback is a duck which obtains food by —9—. Two warm-blooded animals are —10— and —11—.

3. How are green plants fundamental to all life?

Survival of all life depends upon a sufficient supply of food. Yet there is only one source of food—the green plant. No matter how well adapted an animal may be or how good the environment in other respects, if there is not a sufficient supply of green plants to provide food, all other life ceases to exist.

Are all plants green? As you know, there are two types of plants: those which are not able to make food and those which are. The plants which cannot make food are not green. Strictly speaking, foodmaking is not limited entirely to green plants, for there are a few red, brown, or blue-green plants which can make food. The foodmaking plants which are not green are chiefly algae which live in the ocean. The simplest foodmakers are the simple green scums that grow in ponds and in the ocean, and they provide a food supply for many other simple living things.

How do green plants make food? The process of making food is a chemical change—that is, energy is taken in by the plant and is used to change one kind of material to another. The process by which food is made has a difficult name—photosynthesis [fō′tō·sĭn′thē·sĭs], which means "light (*photo*) put together (*synthesis*)."

In order to make food, the plant must have a supply of raw materials, there must be machinery or chemicals in the plant

to do the work, there must be a source of energy, and there must be some way to use the food and get rid of wastes.

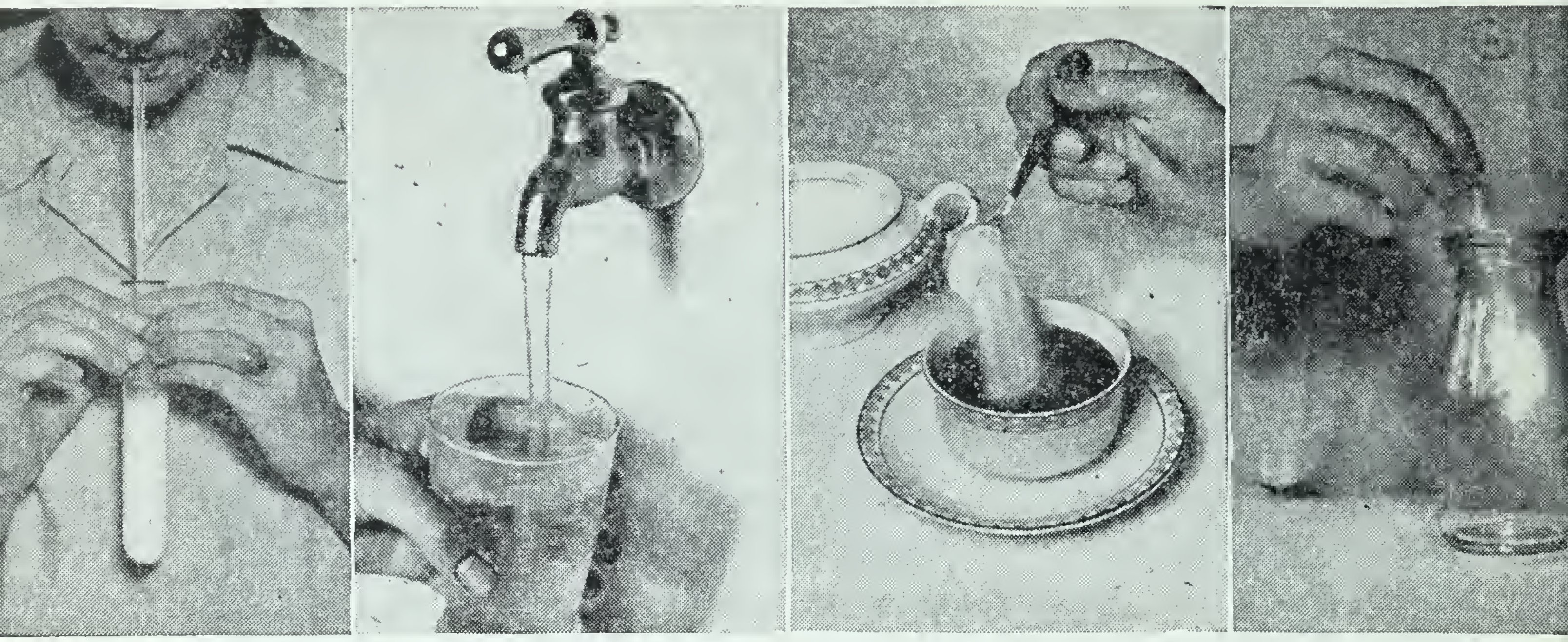
What raw materials are used in making food? The final product obtained as a result of photosynthesis is composed of the three elements carbon, oxygen, and hydrogen. The materials from which the leaf obtains these elements are water and carbon dioxide. The hydrogen is obtained from water, the carbon is derived from carbon dioxide, and the oxygen may be obtained from either water or carbon dioxide.

Water may be absorbed from the soil by tiny hairs on the roots of seed plants, or directly from water by water plants. The carbon dioxide usually has a much shorter journey to make. There is always a small amount of this gas in the air, and most pond and ocean water contains dissolved carbon dioxide. Seed plants take carbon dioxide in through openings in the leaf called stomates. Other plants absorb it directly.

What is chlorophyll? The actual work of making starch is done by the chlorophyll [klō′rō̇·fĭl], which gives the green color to the plant. Chlorophyll is found in the stems of some plants, as in the horsetails and cacti, and in the bark of many young plants. But from a practical point of making food, most of the work of photosynthesis is carried on in the leaves of larger plants. One-celled plants contain the chlorophyll within the cell.

What is the source of energy? The source of the energy used in making food is the sun. The sun is the source of our heat and of most of our light. It is this light that the chlorophyll needs to do its work. The leaf works from sunrise to sunset, and it is only during the hours of darkness that the chlorophyll rests. The length of the leaf's working day varies according to the latitude and the month. In the northern parts of the United States during the longest days of the summer the leaf works from 14 to 16 hours a day.

Leaves can make food in artificial light as well as in sunlight. Experiments have been done to learn the effect on the growth of plants of increasing the number of hours they were kept in the light. Some plants were kept in the light 15 hours daily, some 20, and some were kept in the light all the time. It was found that the plants matured more quickly when kept in the light longer. But there was a limit beyond



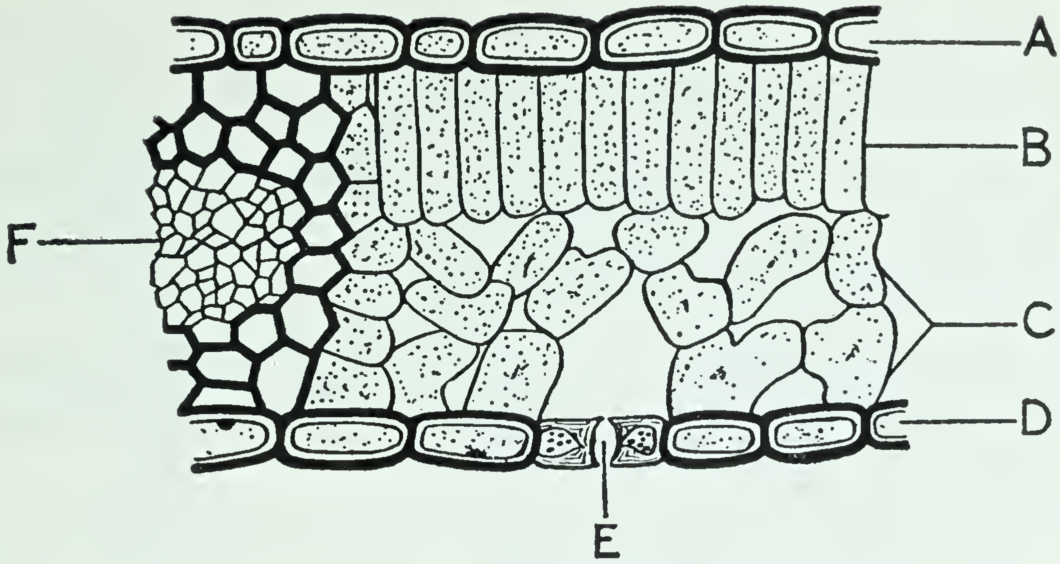
These four pictures show the chemicals taking part in the chemical change: carbon dioxide plus water yield sugar plus oxygen. Explain the tests.

which an increase in the hours of light did not further hasten the growth of the plants.

What product is formed? The products of photosynthesis are carbohydrates. They include both starch and sugar, which are found in the green plant. Probably the first product formed is sugar, which is then changed to starch. These two forms readily change one into the other. The carbohydrate is stored as starch, which is insoluble. The insoluble starch may be changed to a soluble sugar and, in this condition, carried in the sap to all parts of the plant. A square yard of leaf surface makes about three pounds of starch during the summer. In order to realize how much food plants make every year, one has only to think of the huge crops of corn, wheat, potatoes, apples, and foods of every kind that the farmers reap annually. All this food is but a tiny fraction of the food made by plants.

What by-product is formed? The primary function of chlorophyll is to form sugar. But in the process another material, the element oxygen, is given off. All living things and all fires are constantly using up the oxygen in the air. Through the process of photosynthesis, the supply of this valuable element is renewd.

How do plants make proteins? Plants make not only carbohydrates but also fats and proteins. In fact all the food



This cross section of a leaf shows the upper epidermis (**A**), the palisade cells (**B**), the spongy cells (**C**), the lower epidermis (**D**), the stomate (**E**), and the vein (**F**).

supply of the world is dependent on the activities of plants. Since protoplasm appears to be composed chiefly of proteins, the importance of proteins to plants as well as to animals is clear. Proteins contain the same three elements as do carbohydrates—carbon, hydrogen, and oxygen—but in addition they also contain nitrogen and some other elements, such as sulphur and phosphorus. The first three elements are obtained from starch; the other elements are obtained by the plants from minerals in the soil or in water.

The exact process of protein-making is not well understood; but some facts regarding it are known. Proteins are made from starch and mineral salts. Neither chlorophyll nor light is necessary for making protein.

How do plants get rid of water? While the seed plant is making food and giving off oxygen, it is also giving off excess water through the stomates of the leaf. This process is called transpiration [trăn′spĭ·rā′shŭn]. The amount of water thus given off is very large. An experiment carried on in Kansas showed that a corn plant lost nearly two barrels of water in a single season. This was nearly 100 times as much as the plant needed for all purposes except to replace that lost by transpiration. This large amount of water is needed to provide the small amount of mineral salts required by the plant.

As the water reaches the outer surface of the leaf, it evaporates and passes into the air as water vapor. The amount of water lost by transpiration varies greatly from day to day,

depending on such factors as the temperature and humidity of the air. Within certain limits the amount of water transpired is controlled by the guard cells of the stomate. Generally they are open during the day and closed at night. The stomates also tend to close during the day when the supply of water in the leaves is deficient.

DEMONSTRATION. IS THERE STARCH IN GREEN LEAVES?

What to use: Green plant, alcohol, burner, beaker, iodine, pin, black paper.

What to do: On a large green leaf pin a smaller disk of black paper, and leave it for 24 hours. Set the plant in sunlight. Remove the leaf, take off the paper, and boil the leaf in water a few minutes. Dissolve out the chlorophyll in alcohol. With iodine, test the leaf for starch.

What was observed: Did the leaf turn dark blue all over? What does this color indicate?

What was learned: Is starch manufactured in the part of the leaf not exposed to sunlight?

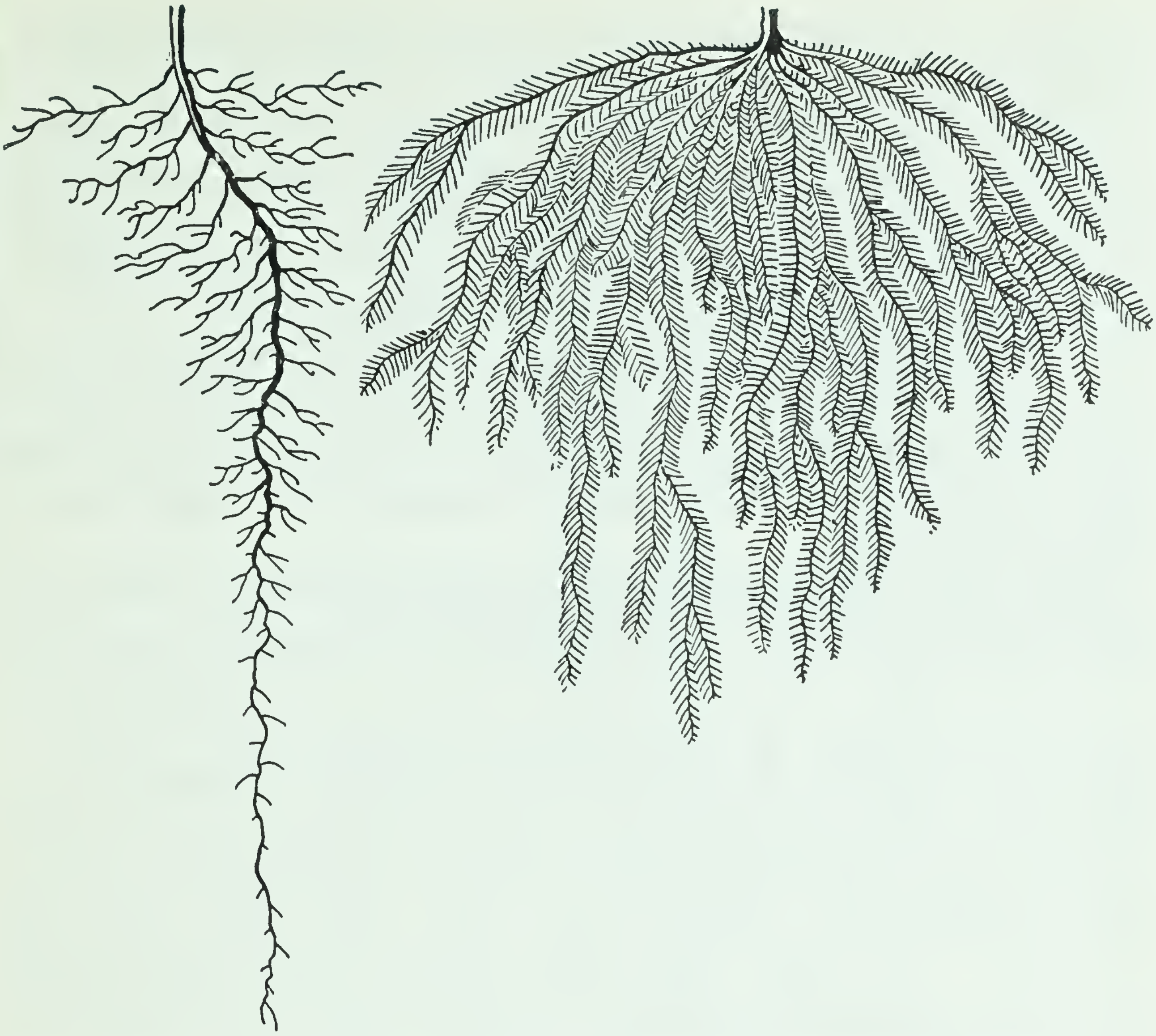
Microscope slide: Cross section and epidermis of leaf.

Exercise. *Complete the following sentences:* Starch is manufactured by green plants from water and —1—. Giving off water by the leaves of plants is called —2—. —3— is the process of making food. In the process of photosynthesis the gas —4— is given off. Proteins are made from starch and —5—. If a growing leaf is placed under a tumbler, —6— will collect on the inside of the tumbler. The energy needed by plants for manufacturing starch comes from the —7—. The green substance in the leaves is —8—. The process of —9— is the basis for the world's food supply. The small openings in the skin of the leaf are called —10—.

Science activity. Find in a reference book microscope views of leaves, and make a soap sculptured model showing a leaf greatly magnified. Put in the various cells, a vein, and stomates.

4. What are some adaptations which help plants make food?

In order to carry on the important function of making food, all plants have special adaptations. Of course the most important of these is the presence of chlorophyll. But other



There are two kinds of root systems common among seed plants. The taproot (*left*) grows downward from the center of the plant and other roots branch from it. Many fibrous roots grow from the base of the plant and spread in all directions.

adaptations are also necessary in order to provide light, mineral food, water, and carbon dioxide to the part of the plant which makes the food. Some sea plants are light enough to float on the surface where they can get light. Other plants root in the lake or ocean bottom and send up long stems to the surface to reach light. While each kind of plant has its own adaptations, it is the seed plants which have the most successful adaptations for getting the things needed for making food.

How do roots help the plant to make food? The root systems of most seed plants are quite extensive. If a small plant is carefully dug up so as to keep all the roots, it will often be found that this system is even larger than the part above ground. Alfalfa plants sometimes send their roots 20 feet deep

in the soil. To include all the roots of a single grass plant, it is necessary to wash away more than a cubic yard of soil.

There are two types of roots, the taproot and fibrous roots. A taproot consists of a single large branch that grows straight down, giving off smaller branches. A fibrous root is composed of many small branches of about the same size. The beet plant has a taproot, and the grass plant a fibrous root.

A root has three main regions. Covering the end of the root, like a thimble on a finger, is a root cap, which protects the tender parts beneath. Just back of this cap is the growing region of the root. The root does not grow in length in any other of its parts.

What causes absorption of water and minerals? The most important part of the root in absorbing water and minerals is the root hairs. They are found only near the growing tips of the young roots. As the roots grow longer, new root hairs appear just behind the tip, the older hairs meanwhile disappearing. They are very numerous, for there are sometimes as many as several thousand to an inch. Each hair is a tiny, hollow tube with a wall so thin that soil water can pass through it. The root hairs cling closely to the particles of soil and increase greatly the surface used for absorbing water.

The process by which the water passes through the walls of the root hairs is known as osmosis [ŏs·mō′sĭs]. The walls of the root hairs act as membranes. The water in the soil is less dense than the cell sap, which contains sugar and other dissolved materials. Under these conditions the water passes from the less dense to the denser liquid. That is, water from the soil passes through the wall of the root hair into the cell sap. The pressure of osmosis forces water upward through the root which serves to carry water to the stem of the plant.

How do roots anchor the plant? In order that a plant may stay where it can obtain a supply of water, it must be anchored in the soil with its root hairs in close contact with soil particles. Roots serve as anchors and foundations of the plant by developing a rigid structure and by wrapping themselves closely around soil particles. Corn plants have roots which serve as braces to support the stem. Almost every plant has some adaptation whereby its roots serve to support the stem.

How does the stem help to make food? The stem has two important functions in foodmaking. It must serve as a transportation system, and it must either support the leaves or itself carry on the foodmaking process. There are two types of stems common to seed plants.

Trees and many other plants have stems with the parts arranged in rings. The outer layer is the bark, the inner layer the woody part, and the part between is the cambium [kăm′ bĭ·*ŭ*m]. The cambium is made up of a layer of cells from which growth proceeds. The inner part of stems more than a year old is really dead, but serves the important function of strengthening the plant. The newly formed wood carries the water and dissolved minerals from the roots to the leaves, while the newly formed bark carries food from the leaves to the roots.

Another type of stem is represented by the corn plant and other grasses. The bundles of tubes which carry water and food are scattered throughout the stem, and in each bundle some tubes carry water up the stem and other tubes carry food down the stem. As seen under the microscope, the larger tubes are the ones which carry water.

For holding the leaves to the light there are many interesting adaptations. The trees grow so tall that they rise above other plants. Some low plants branch in all directions in order to expose the leaves to light as much as possible. Certain plants develop as vines which climb and twine around any support which can be used to hold leaves to light. The grapevine has special stems called tendrils which twist around the support. The leaf stalk of the nasturtium twists around a support to hold up the plant. The woodbine stem produces aerial roots which attach themselves by means of disklike suckers to the support on which the vine is climbing.

The stem of the cactus plant actually makes the food. The leaves are developed as spines and do not contain chlorophyll.

A few plants have stems which grow underground and send up branches at intervals in search of a suitable place for growth. One of the most common of these is quack grass, a plant which is very successful in competing for food and light with other plants. The potato is an underground stem used for storage of food and for providing a place for buds

to develop for growth a year after the potato was formed.

How do leaves help in making food? The leaf is generally the food factory of the plant. In order to reach the light, leaves are provided with petioles [pĕt′ĭ·ōl, leaf stalks] which twist in such a way that the flat part of the leaf—the blade—is turned toward the light. The leaf has a complete system for circulating water and food. This system consists of the veins, which are made up of the same kinds of bundles of tubes as are found in stems. The veins of grasses and related plants are parallel, while the veins of many other plants are arranged to form a network.

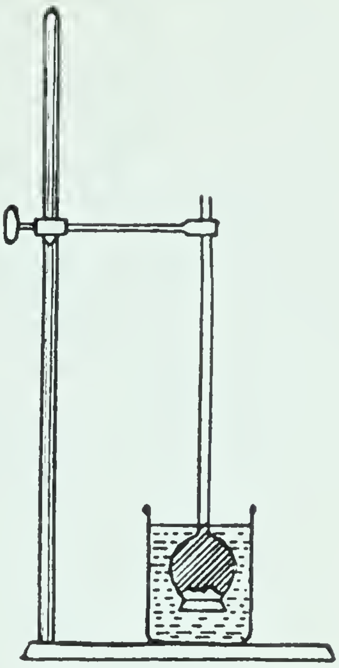
The stem of the bean plant twines around a support to lift the leaves toward the light. Find a grape, a garden pea, and an English ivy to compare with the bean as to their manner of climbing.

What tropisms help the plant to make food? Most of the tropisms of plants are concerned with making food. The turning of the leaf on its stalk to reach light is such a type of behavior. You recall of course that roots grow toward water. This tropism is of utmost importance for the survival of the plant. The tendency of roots, under the influence of gravity, to grow downward and of stems to grow upward is also essential for the success of the plant in making food. The opening and closing of the stomate by the guard cells is another tropism essential to conserving moisture when the plant is becoming dry, as is the rolling of the corn leaf.

Demonstration. What Is Osmosis?

What to use: Thistle tube, pig bladder, sugar, rubber band, beaker, ring stand, stopper.

What to do: Put the stem of the thistle tube in the stopper. Fill the funnel end of the thistle tube with thick sirup, holding a finger over the small end to keep the tube full of air. Put the pig bladder or a sausage casing over the large end of the tube. The sirup should rise in the stem about an inch. Put the large end of the thistle tube in a beaker of water, with the level of the water and of the sirup the same. Support the tube on the ring stand, as shown in the diagram, by holding the stopper with a clamp.



What was observed: Can you see that the water has risen in the tube at the end of an hour? At the end of 24 hours?

What was learned: What happens in the process of osmosis?

Microscope slide: Cross section of root.

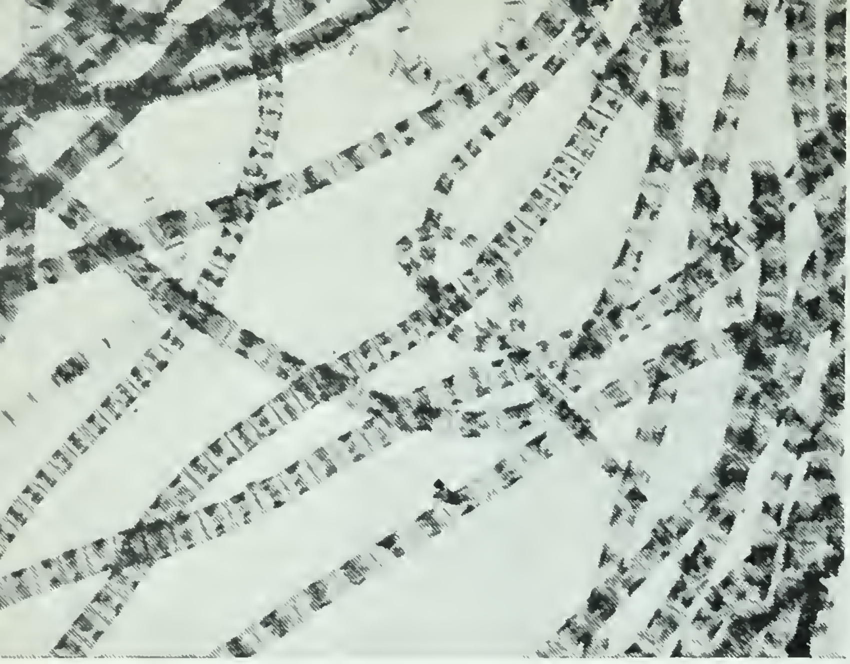
Exercise. *Write a paragraph summarizing this problem, using in it the following words:* root hairs, osmosis, wood, bark, bundles of tubes, cambium, minerals, water, sirup, stomate, light, food, tropism.

Science activity. Put different kinds of roots and stems, such as willow twigs, potatoes, carrots, and geranium stems, into colored ink. Let them stand overnight, and cut into the stems or roots to see how far the liquid has risen.

5. How are different plants adapted for survival?

There are many kinds of plants upon the earth, each different in structure and adaptations from all other kinds. Yet in spite of the minor differences between plants, they still are adapted in general to carry on their life processes in similar ways. All plants of each large group solve the problem of reproduction in a similar way: one group by cell division, another by development from spores, and another by growth from seeds. Because of these fundamental similarities, we can best study plants by learning to place them in groups where they naturally fit.

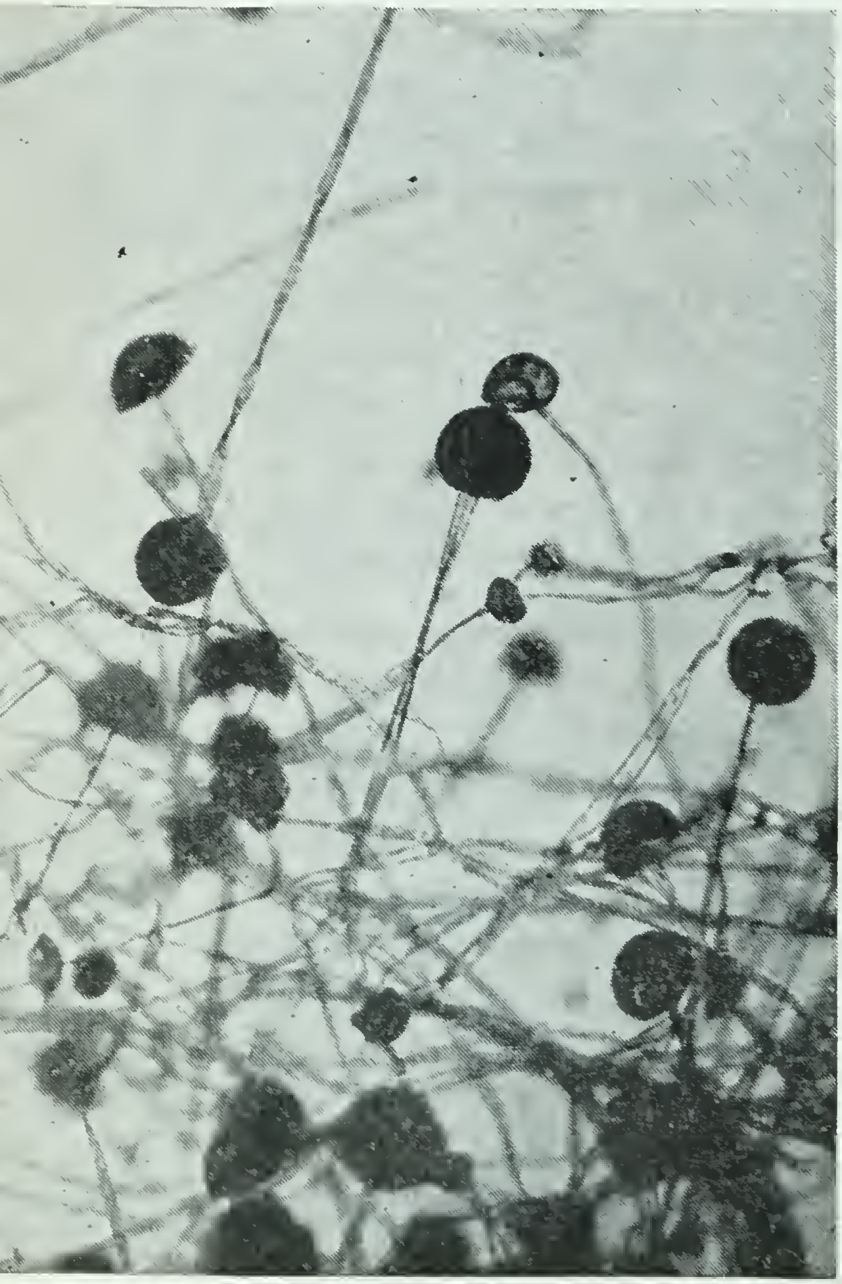
What are the adaptations of the simplest of plants? There are two distinct types of simple plants. One type, the algae, is capable of manufacturing its own food. The other type,



Hugh Spencer photo

The algae above are made up of similar green cells which grow in chains. The bread mold below is threadlike, taking its food from the bread. The black circles are spore containers.

Hugh Spencer photo



the fungi, obtains its food from either living or dead materials.

The algae may live in either fresh or salt water. Some grow on the trunks of trees. The pond scum seen growing in masses in ponds is composed of a great many algae plants. When examined under a microscope, this mass is found to consist of slender threads, each made of similar cells joined end to end. The algae occur in a variety of colors—green, red, and brown. The Red Sea gets its color from the algae living there. Brown and red algae which can live in hot water give color to the mammoth hot springs in Yellowstone Park. Many algae are composed of but a single cell.

Fungi have no chlorophyll. If they use living matter as food, they are called parasites [păr′ȧ·sīts]. If they attach themselves to dead matter, they are called saprophytes [săp′rō·fīts]. Some of the fungi that take food from living plants are the cause of plant diseases. Rust on wheat and blights and mildews on other plants are examples. Bacteria and yeasts are very common fungi.

Mushrooms or toadstools are the only fungi recognized

by most people. The common distinction between mushrooms and toadstools is that the former are safe to eat, while the latter are poisonous. But to a botanist the two words mean the same thing. Some of the nonpoisonous forms look very much like the poisonous varieties, and these cannot be told apart except by experts. Generally it is not safe to pick your own mushrooms for eating.

The part of the mushroom which we see above the ground is only the reproductive part. Below the ground are rootlike parts which absorb the food from things on which they grow. This is a useful adaptation for the environment. The parts underground are located where the food supply is. And since they cannot make their own food, they have no need for light. Location of the reproductive part above the ground makes it easier for the spores to be spread.

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This poisonous fly mushroom is typical of the most commonly known group of fungi. The portion seen above ground produces spores.

Mushrooms occur in a great variety of shapes. One of the most common is the umbrella shape. The top part is called the cap. On the underside of the cap are found gills in some plants and holes in others. If the cap of these gill mushrooms is cut from the stem and placed gills down on a piece of paper, the spores will drop out to make a spore print. The lines of this spore print are arranged like the spokes of a wheel. The spores, however, differ in color. They may be black, white, pink, or brown.

Puffballs are another common form of mushrooms. When they are ripe they are filled with millions of tiny spores, which puff out as a powder when the puffball is squeezed.

This group, including both fungi and algae, which generally is called thallus [thăl′*u*s] plants, contains in all about 80,000 different kinds of simple plants.

What are the mosses? The mosses are more complex in their adaptations than thallus plants. They do not need to live either in or close to water. However, they are rarely found in extremely dry regions. The plants are not more than a few inches high. They may be found on the ground, on rocks, or on tree trunks. All of this group are green and are therefore able to manufacture their own food.

They have stems and leaves but no flowers. Their system of reproduction is more advanced than that of the thallus plants. The moss reproduces in a complex way by developing through two stages. One stage produces a plant which develops the egg and sperm [spûrm, that part which is needed by the egg to help it grow]. From this plant there grows a second plant which produces the spores which are then scattered.

The mosses are generally unimportant. One kind, accumulating over long periods of time, forms peat bogs. Because the bog mosses absorb large quantities of water, they are much used as packing materials for living plants.

What are ferns? Did you ever see a "fiddlehead"? This name is often given to the opening buds of ferns. Instead of opening as do the buds of trees, they unroll upward from the inside. On these buds you can find a fine plant down. Some birds use this down to line their nests.

In the spring new fern leaves grow outward from the old plant, leaving the central area without leaves. This circular arrangement of new fronds is sometimes called a fairy ring.

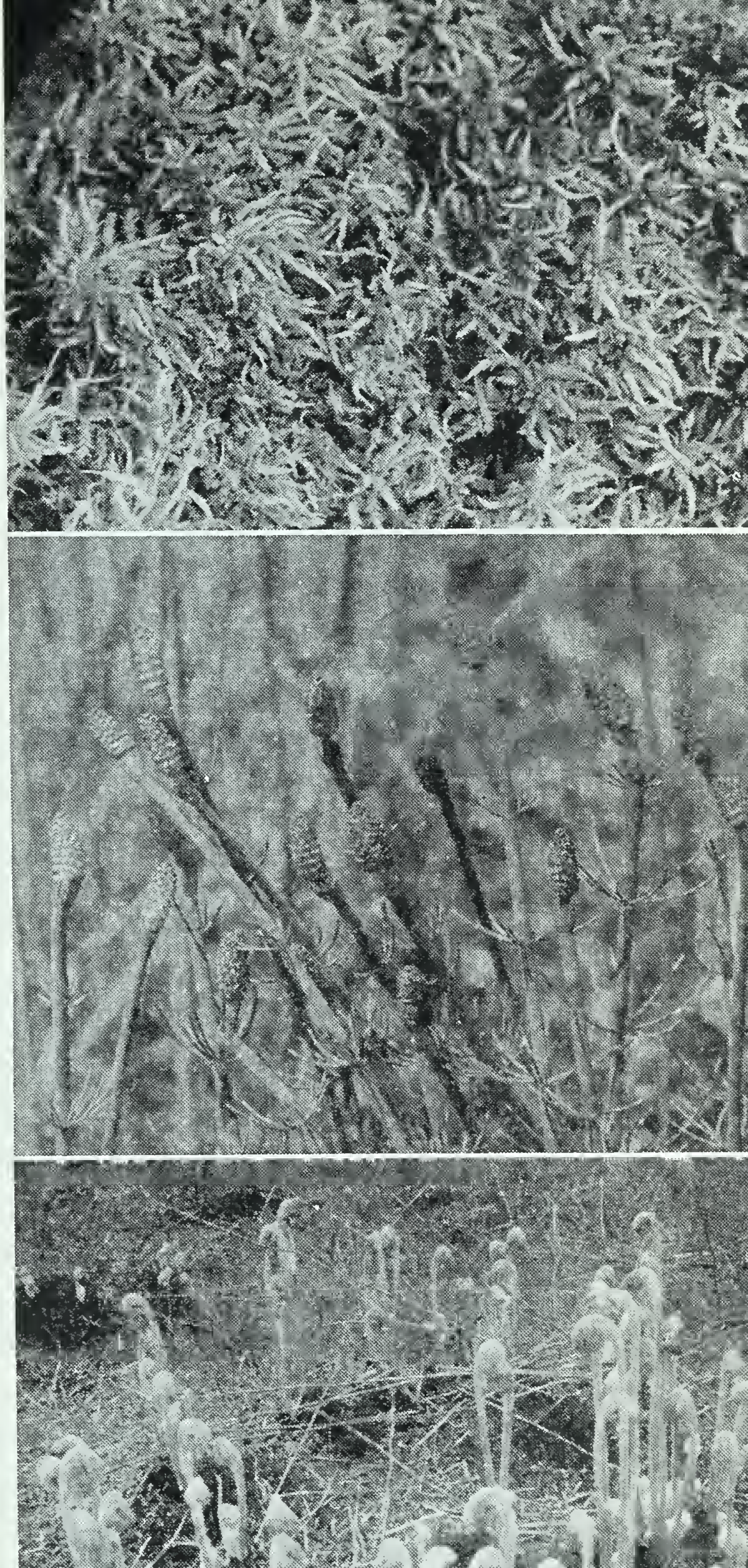
The part of the fern plant that you most commonly see is the leaf, also called a frond [frŏnd]. The leaves are generally divided into smaller parts, each part looking like a separate leaf. The stems are generally found underground, although in the tropics the main trunk may extend as much as 10 to 50 feet above the ground. At the top of this trunk is attached

a mass of great leaves which may be as much as 20 feet long. Most ferns grow only in shaded positions, commonly being found in moist woodlands or shaded ravines. The horsetails are weedy plants related to the ferns. They usually grow in thin, moist soil.

Fossils found in coal beds show that millions of years ago these plants grew to be the size of trees. Our coal beds were formed from the remains of these ancient fern forests.

What are seed plants? Because they are well adapted to their environment, there are more kinds of seed plants than all the other kinds of plants combined. These are the only plants that reproduce by means of seeds. Since the flower is the organ which produces seeds, all of these plants possess some sort of flower and develop some kind of fruit. They have well developed roots and stems. The method of branching and form of leaf are important means of identifying the different members of the seed plants.

Seed plants bear their seeds in one of two ways. Most of the evergreens, such as the pines and spruce, bear their



L. W. Brownell photos

Top, the type of moss that grows in swamps; center, horsetails showing spore containers; bottom, ferns in the "fiddlehead stage."

seeds in cones and are therefore called conifers [kō′nĭ·fẽrz]. The second group of seed plants produce their seeds inside of some seed container. The seeds of some of these plants have a single seed leaf, while other seeds have two seed leaves, and still others have many seed leaves. Corn, wheat, lilies, and tulips produce seeds having only one seed leaf. The common trees, shrubs, vines, and most of the plants of the vegetable garden produce seeds having two seed leaves. The big trees, or giant sequoias [sē·kwoi′ȧs], of California produce seeds having many seed leaves.

How may plants be classified? The plant groups just described are classified as they are because all members of a given group are similar in structure. The present system of plant classification was developed by Linnaeus [lĭ·nē′ŭs] during the eighteenth century, and the methods of classification which the botanist uses today follow his suggestions.

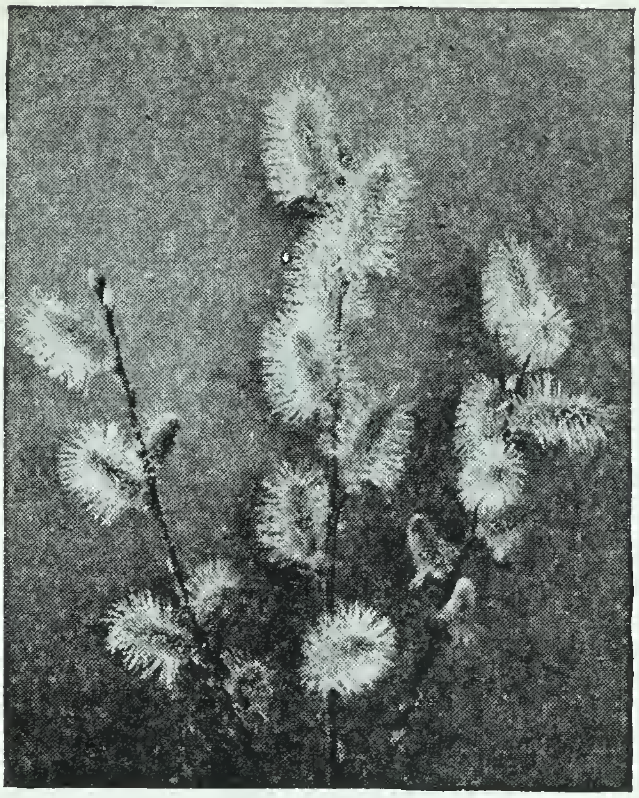
Thus we see that there are four large groups of plants: seed plants, ferns, mosses, and thallus plants. Within each of these groups the plants are further subdivided into smaller classes and these, in turn, into still smaller groups. Sometimes the classifications of the scientist are surprising to us, because we are likely to classify plants on the basis of their use rather than their structures. Thus, to us the rose is a flower and an apple is a fruit, but to a botanist they are both members of a very closely related group.

Slides (2x2 inch): The great groups of plants—MK02. Chicago Apparatus Co.

Filmstrip: Mushrooms and toadstools. Pickwell.

Exercise. *Make a table by ruling your paper into four columns. Head the columns as follows:* THALLUS PLANTS, FERNS, MOSSES, SEED PLANTS. *In the correct column write the following words:* algae, bacteria, corn, petunia, yeast, hollyhock, horsetails, peony, molds, mushroom, elm tree, rock moss, Boston fern.

Science activity. Make a collection of plants, trying to get two examples of each of the three simple types of plants and 10 seed plants. Most plants can be pressed and kept dry. Label each plant according to the type to which it belongs. Some dried plants may be kept from shattering if dipped in paraffin. Plants may be kept in cellophane envelopes.



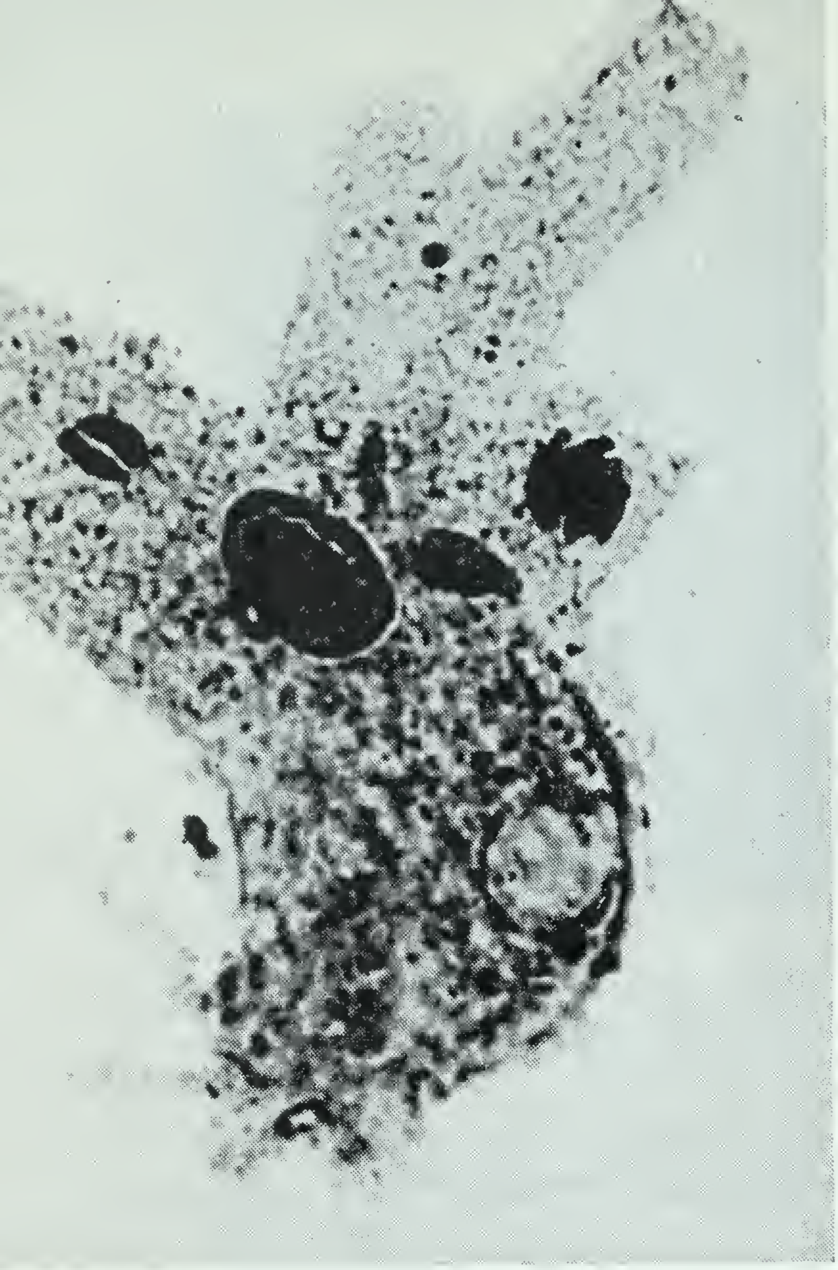
Only seed plants bear flowers. The apple blossoms are the type of flower which we commonly refer to as being typical flowers, but the pussy willow is just as truly a flower as the other.

6. How are simple animals adapted to survive?

We generally know little about the simplest animals, because they are small and because they are not directly important to us. Yet there are at least 10 large groups, or phyla, of animals so simple that they have not developed an internal skeleton for support of their bodies. These animals range in size from one cell to several hundred pounds in weight, and vary just as much in structure as in size.

What animals are made up of one cell? We cannot hope to become familiar with all the 15,000 kinds of one-celled animals. These microscopic animals may live in the sea or in fresh water, in the bodies of other animals, or on moist soil. You can obtain specimens for study by putting a handful of hay in water or by putting water weeds in a battery jar. In the scum that forms on the surface of the water one-celled animals usually can be found.

A common animal grown in this way is the amoeba [ȧ·mē′bȧ]. It is about 1/100 of an inch long, and is a nearly colorless, jelly-like mass of irregular shape. The nucleus is visible under the microscope. The cell constantly changes



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Although the amoeba is called the simplest animal, its one cell carries on many complex life functions. Can you see its nucleus?

shape as its protoplasm moves to form bulges on one side or the other. Motion by this means is slow. To obtain food, the ameoba wraps its body cell around material it comes in contact with, digests what it can by chemicals produced in the cell, and then moves away, leaving the undigested material behind.

Another animal found in the scum from the jar of water is the paramecium [păr′*ȧ*·mē′shĭ*ŭ*m]. It is also a one-celled animal, but it has a definite shape—somewhat like a slipper with a pointed toe. Along one side is a groove which leads to a mouth. Inside the cell a tiny droplet forms in which wastes accumulate, and this drop is thrown off through the cell wall. The cell is covered with hairlike growths called cilia [sĭl′ĭ·*ȧ*], which are used to produce movement. The paramecium rotates as it moves either forward or backward, by whipping its cilia in the water.

Are sponges animals? Sponges always live in water, and usually in salt water. They lie anchored on the bottom of the sea or lake, and depend upon currents of water to bring them food. The cells grow in vase-shaped groups. Water is circulated into the open end by means of cilia, then into the central cavity, and out through the open end. The cells lining the pores digest food and pass the digested food along to other cells. These vase-shaped groups of cells may form huge clusters, or may be almost microscopic in size. The common bath sponge is made up of skeletons of many animals. The skeletons of sponges are not internal skeletons, but rather

are made up of horny fibers or glassy or limy materials.

What animals have hollow bodies? There are several groups of animals—the corals, the hydras, the sea anemones, and the jellyfishes—which have hollow bodies. All live in the water, and most of them live in salt water.

The hydra is found in fresh water, and is not more than a quarter of an inch long, and about as thick as a pin. It is made up of a hollow tube, and attaches one end to a stick or other support. The free end has a row of six or seven finger-like arms, arranged around an opening called the mouth. These arms are used in obtaining food. On these arms are many small stinging cells.

The hydra moves in various ways. It waves its arms and expands and contracts its body. It can also move along by sliding the lower end of its body along its support, or it can move like a measuring worm. It sometimes walks by using its arms as legs, or moves by turning slow somersaults.

The corals live in warm, shallow water in huge colonies. They build a kind of skeleton of lime. Each generation grows on top of the preceding generation, leaving behind materials which become part of the rock. The Great Barrier Reef of Australia, which was formed by corals, is more than a thousand miles long. Other types of corals form circular islands called atolls. Others grow near shore to form shore reefs. The corals are thus important rock-formers.

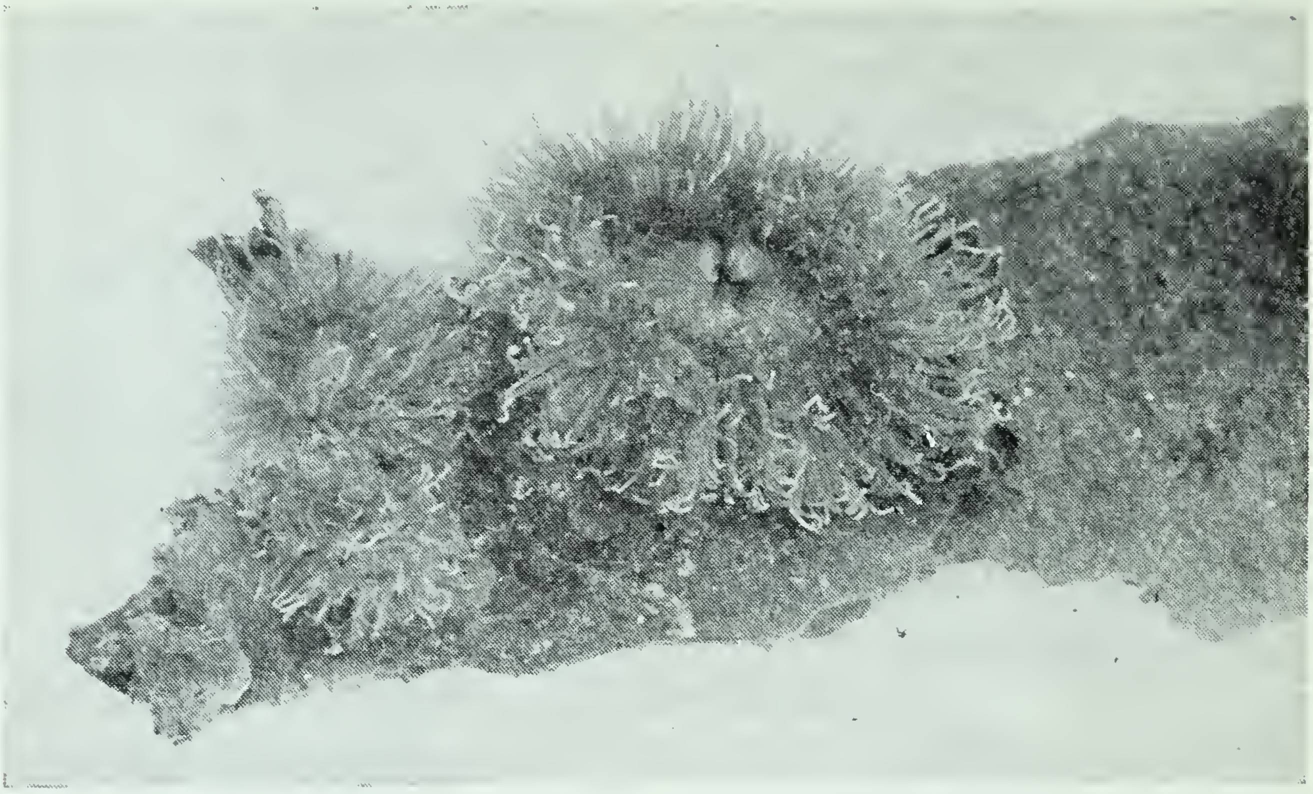
The sea anemone can commonly be found on rocks along the seashore at low tide. It looks as much like a flower as an animal.

Jellyfish usually are free-floating animals, and are about 97 per cent water.

How is the starfish adapted to live? There is an interest-

Hugh Spencer photo

The hydra is one of the small hollow-bodied animals. Note that one of its arms is contracted. Where is the hydra found?



L. W. Brownell photo

The sea anemone looks more like a flower than an animal. Its body is hollow, and it takes food into its central cavity.

ing group of animals with their parts arranged like the spokes of a wheel. This group includes the starfishes, the sea urchins, the sand dollars, sea lilies, and sea cucumbers. The most common of these is the starfish, which lies mouth down on the sand along the seacoast. The mouth is in the central part and is surrounded by five arms. The animals of this group have spiny skins, and generally are quite firm in structure.

How do the worms live? There are several groups of worms, each different from the others. The flat worms are simple in structure and are usually parasites in the bodies of other animals. Some live in snails, some in fish, some in higher animals. The tapeworm of man is such a worm, as is the liver fluke of sheep.

The roundworms are also often parasites, and are simple, tubelike animals. The hookworm and the trichina worm, which cause human illness, are members of this group.

The most complex worms are segmented, that is, their bodies are divided into ridges separated by grooves running around the body. The earthworm lives in moist soil through which it burrows to obtain food. In making a burrow, the soil passes into the worm's mouth, through the stomach and

intestine, and out of the body. The worm backs up to the surface to get rid of the soil, which is left at the opening of the burrow in little piles of dirt called castings. In this way the worm is able to burrow deep into the soil, usually to a depth of three or four feet. The earthworm comes to the surface at night to feed.

Because the worm breathes through its skin, it must be kept moist. This explains the fact that we see earthworms above ground only after rain.

Earthworms have simple nervous systems, quite complex digestive systems, special organs for getting rid of wastes, and means of circulating body fluids. They produce sperm and egg cells and reproduce by laying eggs.

What animals have soft bodies? There are more than 60,000 different kinds of mollusks, which are the soft-bodied animals. This group includes snails, clams, oysters, squids, scallops, and octopuses. Most members of this group have a shell which grows from a thin membrane, called the mantle, lining the shell. The shell is made of calcium carbonate, or "lime." Most members of this group have a muscular *foot* which contracts and expands to do the work of moving, digging, and holding to surfaces.

These long, or soft-shelled, clams belong to the group of mollusks which are the soft-bodied animals. Why does a soft-bodied animal need a shell?

L. W. Brownell photo

Hugh Spencer photo

These three garden snails live on land. They leave a trail of slime.

The snails have a single shell which is coiled spirally. Most snails live in water, but a few live on land. The common snail has a head, bearing a mouth and arms, and a foot used for crawling. The slugs are similar to snails, but have no shells and live on land.

The oysters, clams, and scallops have shells divided into two parts, called valves. These are hinged on one side so that they may open or close. Most of this group live in salt water, though some live in lakes and rivers. All have means of circulating water through their shells and bodies to provide a supply of food and air, and to remove wastes. If you have a clam in your aquarium you can see the current of water it sets up.

The shellfish are quite complex, for they have well-developed digestive and excretory (waste eliminating) systems. Their nervous systems are simple. They reproduce by means of eggs.

The large mollusks are the octopuses, the cuttlefish, and the squids. Some members of this class have no shell at all. The cuttlefish has an internal skeleton. Some members of this family can move in a peculiar way. They fill an opening called the mantle cavity with water, and suddenly force it through a small tube. They move rapidly through the water on the principle of a rocket.

The squid can protect itself by ejecting into the water an inky fluid which conceals it from its enemies. The octopus and squid have a row of arms adapted for seizing their prey. The mouth is in the central part of the body.

Slides (2x2 inch): Invertebrate animals—MK06. Chicago Apparatus Co.

Microscope slide: Amoeba, paramecium.

Exercise. *Make a table by ruling your paper into five columns. Head the columns as follows:* ONE-CELLED ANIMALS, HOLLOW-BODIED ANIMALS, SPINY-SKINNED ANIMALS, WORMS, MOLLUSKS. *Classify every animal mentioned in this problem in the correct column.*

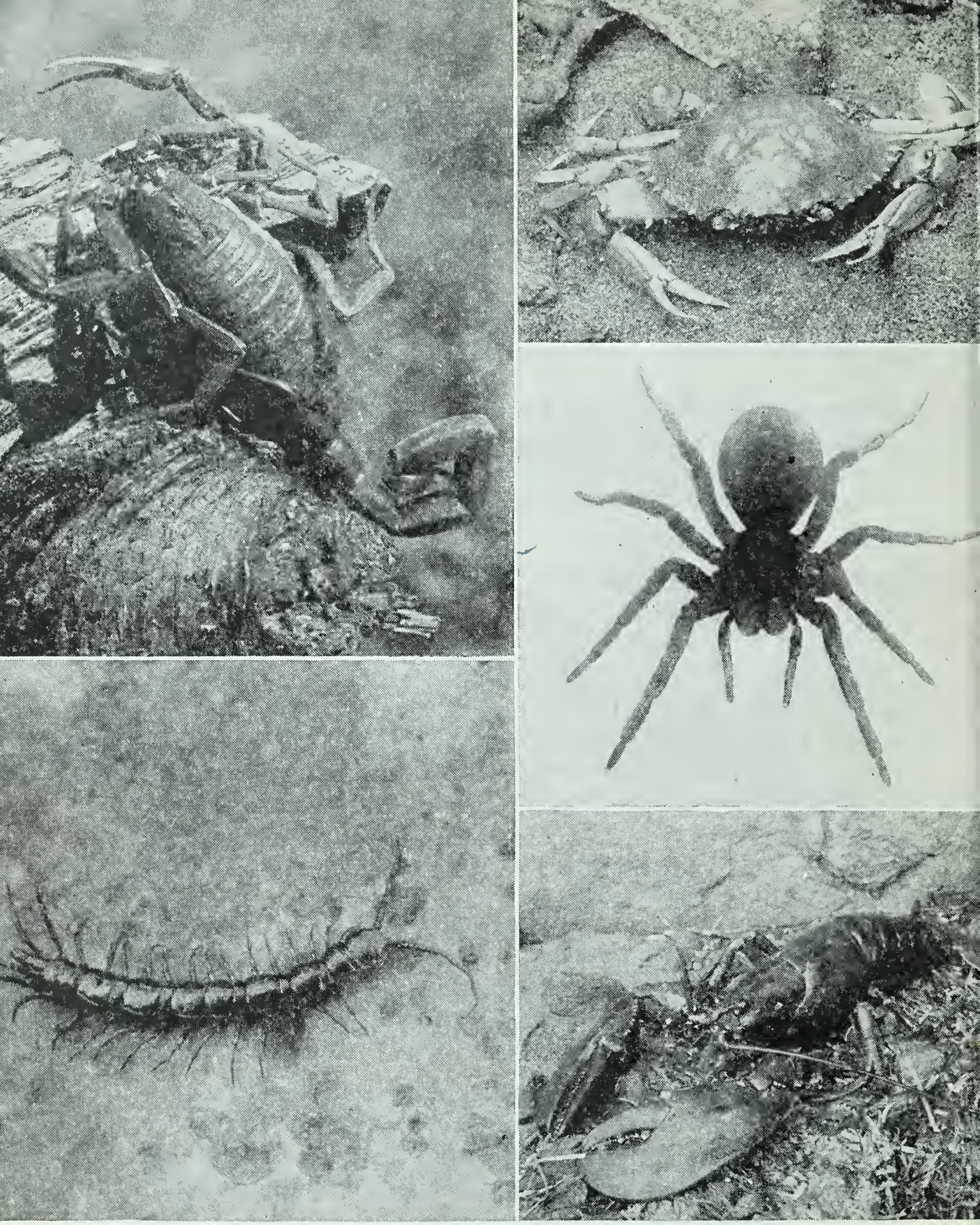
Science activity. Look up in a reference book one of the animals named in this problem, and report on it in class. Mention what it eats, where it lives, how it reproduces, and how it protects itself. If you can, make a large drawing to show the class.

7. How are animals with jointed feet adapted for survival?

As long as animals are limited in activities by simple structures, they do not adapt themselves well to complex environments. You probably have noted that most of the simple animals live in the sea or in some other place where the problems of getting food and surviving did not require any complex behavior. It was not until the development of a satisfactory skeleton and the resulting improvement in means of movement that any group of animals became outstandingly better adapted for survival than others.

Today the arthropods [är′thrō·pŏd, animals with jointed feet] greatly outnumber the other animals. There are more than three times as many kinds of arthropods as of all other kinds of animals combined.

The amazing success of the arthropods results from several features of their structure. They have skeletons made of a strong, light material called chitin [kī′tĭn]. The skeleton is located on the outside of the body in such a way that it serves to protect the complex inner structures of the animal. It also serves as a framework on which wings and legs are attached to act as levers. Muscles are attached to the skeleton. The arthropods can move more effectively than can any other group of animals.



Center right, © General Biological Supply House; all other photos by L. W. Brownell

These animals represent five groups of the arthropods. How do you recognize the centipede, the crab, the spider, the lobster, and the scorpion?

All arthropods have quite well-developed nervous systems to coordinate their complex organs. This nervous system operates by inherited patterns—that is, the behavior of arthropods is instinctive and complex.

The arthropods include several large groups of animals—insects, spiders, crayfish, crabs, lobsters, centipedes, shrimps, sow bugs, and barnacles. The three biggest groups of arthropods are the insects, the hard-shelled animals, or Crustacea, and the spiders.

What are the hard-shelled animals? The hard-shelled animals—the lobsters, crayfish, and crabs—generally live in water. They vary greatly in size, for the smallest are almost microscopic, while the largest lobsters may attain a weight of 14 pounds. They breathe by means of gills.

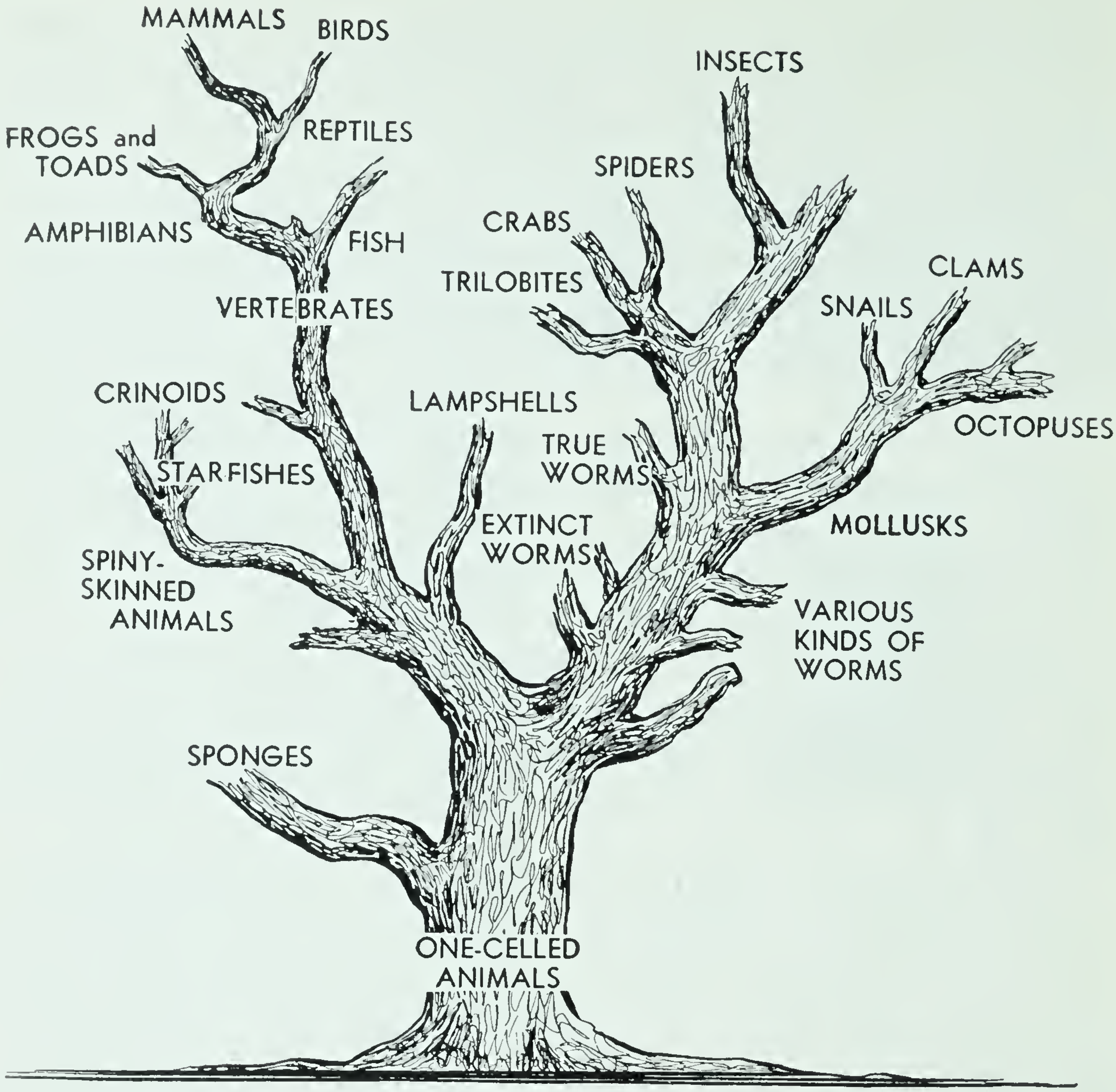
The crayfish is a typical crustacean [krŭs·tā′shăn]. It is found in rivers and lakes, where it hides under rocks and logs by day. From its hiding place it comes out at night to feed. It eats meat. Crayfish make interesting aquarium animals.

The crayfish grows inside its skeleton, but the skeleton does not increase in size. When the crayfish is too big for its skeleton, the old skeleton splits down the back, and the animal crawls out, leaving the old shell. It then grows a new skeleton. This process of shedding the shell is called molting.

There are many appendages upon the body of the crayfish. The large pincers serve for defense and attack. Some of the others serve as sense organs, some serve as means of securing and chewing food, and some of the smaller appendages on the thorax, or midsection, serve as legs. These appendages have the unusual power of growing if broken off. Growth starts at a certain joint and continues until the new appendage is as large as the old.

What are the spiders and their relatives? The spiders and their relatives are numerous. They live on land, and have either book lungs or breathing tubes, or trachea, or both. All members of this group have eight legs, and do not have antennae, or feelers. Some of them — the scorpions — have pincers. All of this group eat by sucking the juices from their prey.

Scorpions are noted for their poisonous sting, which is



This "tree" shows the relationship existing between different groups of animals. It is believed that the animals on the higher branches developed through stages similar to the simpler forms below them on the same branches.

located at the end of the jointed abdomen, or "tail." They live in the warmer sections of the United States. Their food consists of large spiders and insects, which they seize with their pincers and sting to death. Scorpions do their hunting at night.

The spiders are also eight-legged animals, but they have no pincers and no poison sting. The head and thorax are grown together, and the abdomen is not divided into segments or joints. Most spiders have four pairs of eyes.

The webs of spiders serve not only as traps to catch food, but as elevators and bridges. Many spiders travel by spin-

ning threads which are carried by air currents, taking the spider along. Some spiders spin bags in which they carry their eggs. Others spin bags, but after filling them with eggs leave them in a safe place for the young to hatch. Some spiders carry their young on their backs.

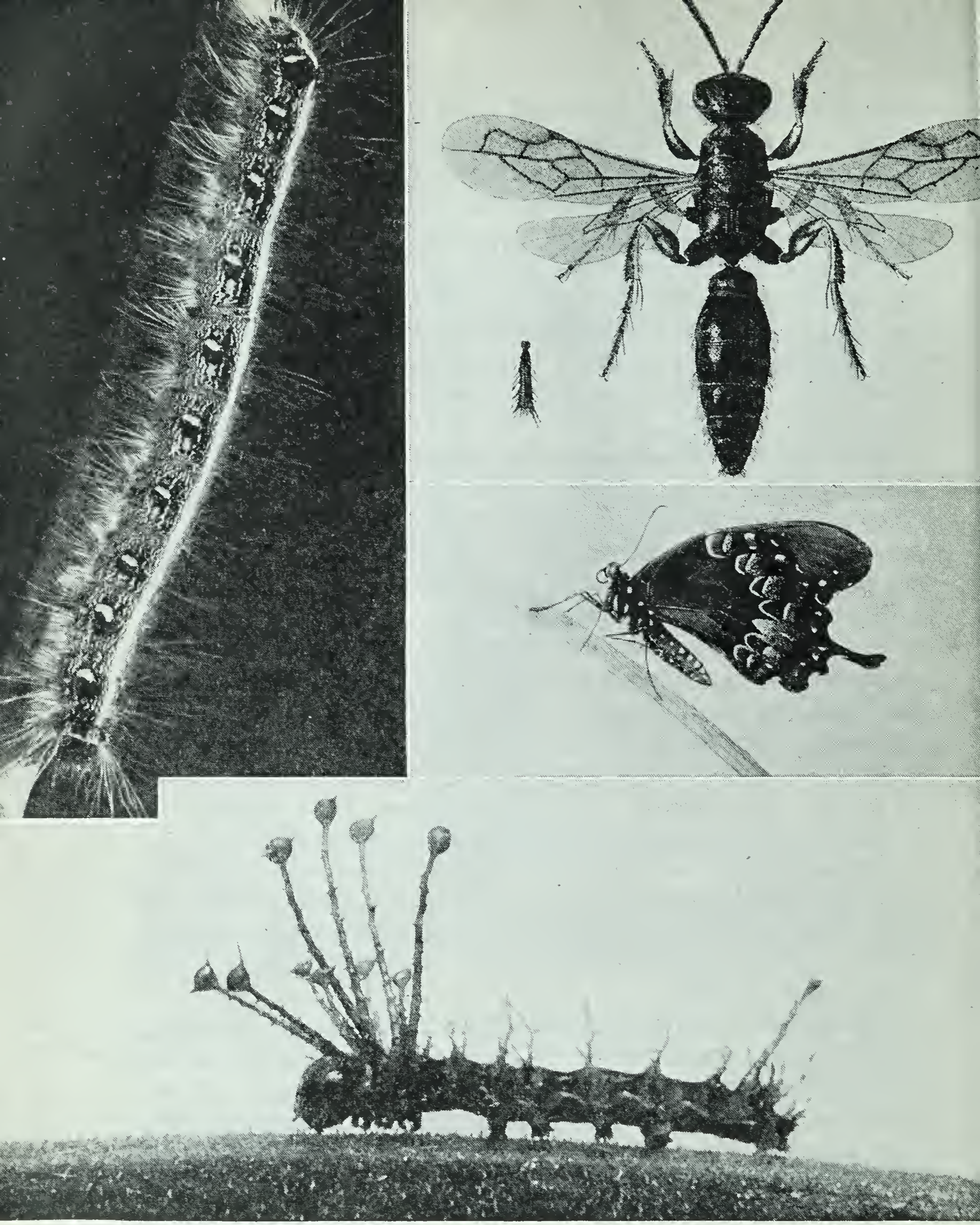
The only deadly poisonous spider in the United States is the black widow female, which is glossy black, with a red or orange hourglass marking on the underside. The tarantula bite is somewhat poisonous but not deadly. Many spiders can bite, injecting enough poison to cause painful swellings.

How are the insects specially adapted for survival? In some ways the insects are the world's outstanding specialists. They are better adapted for flying than are any other animals except birds. Some insects have the most highly developed social groups except those of man. Some insects are clever builders. Others are fierce fighters.

The insect differs from the spider and crustacean in several important ways. Its body is divided sharply into three parts: the head, the thorax, and the abdomen. A few insects have no wings. One large group, which includes flies and mosquitoes, has one pair of wings. Most insects have two pairs of wings. All insects have six legs, and have feelers, or antennae, on the head of adult forms.

The small size of insects is a distinct advantage, for they can hide easily, and require a relatively small supply of food. The tough skeleton and light weight of an insect makes flying at high speeds practical, for it does not dash itself apart upon landing.

Insects are able to produce large numbers of offspring, which is also an advantage. The average female insect probably lays about a hundred eggs, although some may lay many more than this. Insects may grow rapidly. A female housefly lays 150 eggs which develop into adult flies in two weeks. It is estimated that if all the descendants of a female plant louse lived, at the end of a single summer they would be numerous enough to form a chain around the world. Some insects in their development may go through four stages—egg, larva, pupa, and adult—while others grow through three stages—egg, nymph, and adult. Insects in the larva stage are special-



Center right, © General Biological Supply House; all others courtesy U. S. Bureau of Entomology and Plant Quarantine

The adult insects are a female black digger wasp (*top right*) and a swallow-tailed butterfly (*center right*). The larvae are a tent caterpillar (*top left*) and a hickory horned devil (*bottom*).

ized for eating large amounts of food in order to grow rapidly. Many insects provide special care for their young.

Although the behavior of insects is not intelligent but instinctive, they are able to carry on activities of the most complex sort. The female mud-dauber wasp will catch and sting spiders until they are paralyzed, and put them into the nest with her eggs to provide her young with food. The helpless spiders cannot harm the young wasps, but because they are alive they do not decay or spoil. The young wasps are assured a supply of fresh food, although the mother never sees them. For when the female mud dauber has completed her task, she caps the egg cells over and leaves, never to return.

What are some other arthropods? The millipedes are commonly called thousand-legged worms, and the centipedes hundred-legged worms. Both are made up of many segments. The centipedes have one pair of jointed legs on each segment, while the millipedes have two pairs of legs on each segment. Only the centipedes have poison jaws. The millipedes eat vegetable matter, but the centipedes eat insects.

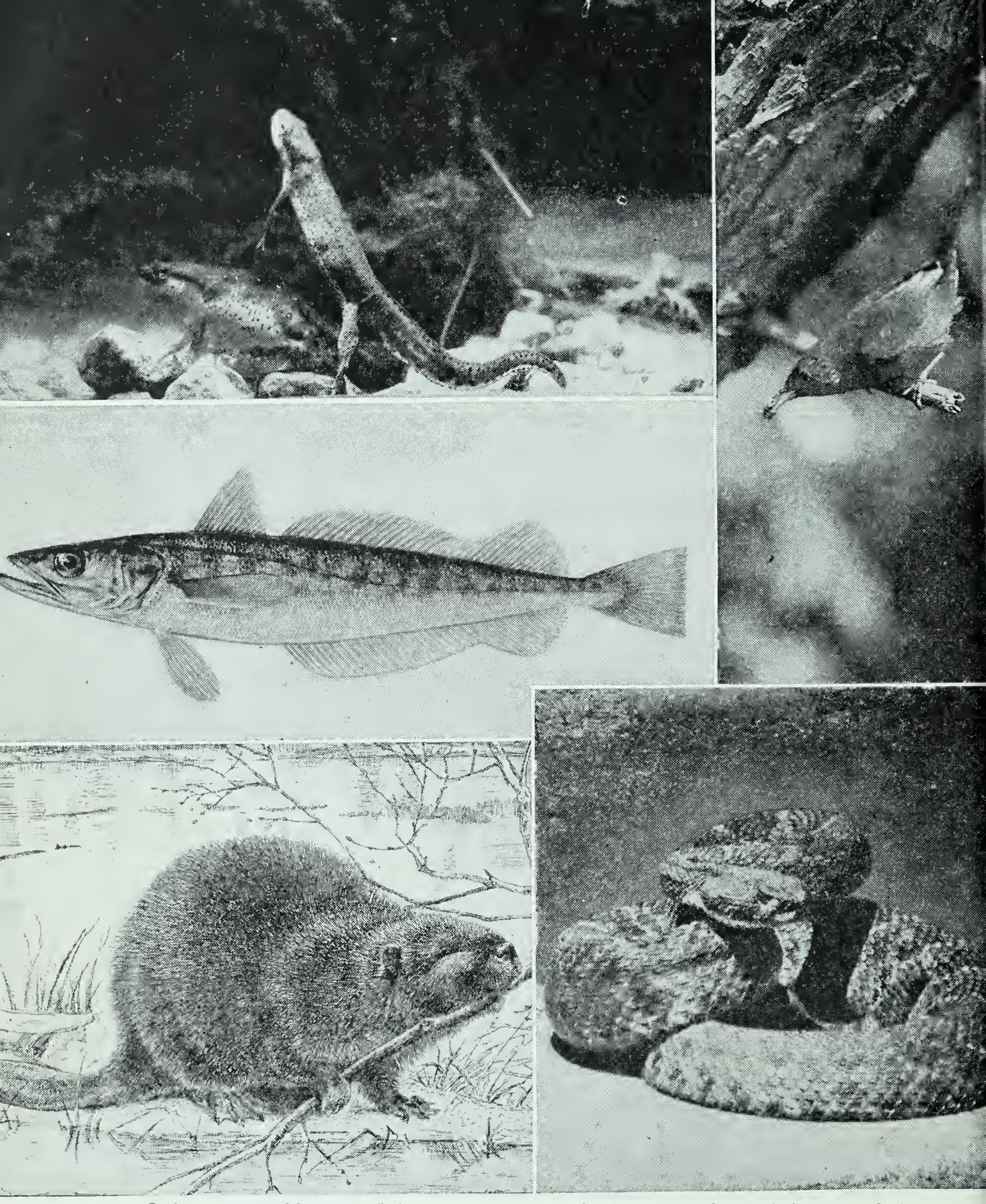
The ticks and mites are dangerous parasites that suck blood from poultry, game animals, farm animals, and human beings. In addition to being unpleasant and tending to weaken the animal on which they live by withdrawing blood from it, these parasites carry a number of dangerous diseases.

Filmstrip: Anatomy of the honeybee. U.S.D.A.

Exercise. *Complete the following sentences:* The animals which have jointed feet are called —1—. They have a —2— outside the body. The crayfish and crabs live in —3— and breathe by means of —4—. The spiders breathe by means of —5—. The bodies of —6— are divided into three parts. —7— have eight legs while —8— have six. The only arthropods with wings are —9—. The —10— stage of insects is especially adapted for foodgetting. The —11— include the lobsters, crabs, and crayfish.

Science activities. 1) Introduce into the school aquarium some crustaceans which you find in ponds or streams. Study them.

2) Make a collection of insects, classifying them according to orders. You will need to study an insect book to do this. Mount them in a cigar box by pinning them through the thorax. Insects may be killed by dropping them into rubbing alcohol.



Left, center and bottom, U. S. Fish and Wildlife Service; top left, Hugh Spencer photo; top right, L. W. Brownell photo; and bottom right, Sharp and Dohme

These five animals represent the five large groups of vertebrates. The newts (*top left*) represent the amphibians; the whiting (*center left*) represents the fish; the beaver (*bottom left*) represents the mammals; the wren (*top right*) represents the birds; and the rattlesnake (*bottom right*) represents the reptiles.

8. How are animals with backbones fitted for survival?

Most of the common animals are those with backbones. They are classified together in a group called the vertebrates. Three of the five classes in this group are cold-blooded, and two are warm-blooded. The cold-blooded animals—the fishes, reptiles, and amphibians—are not really cold-blooded, but instead have the same temperature as the surroundings. Their blood may be warm or cold, depending upon the weather. The warm-blooded animals always maintain the same temperature, which for most animals is about 100 degrees Fahrenheit. Birds ordinarily have higher temperatures than do mammals.

All vertebrates have skeletons inside the body, with the backbone serving as the main structure upon which the body is built. Most vertebrates have four appendages—wings, legs, arms, flippers, or fins. A well-developed head is characteristic. In the head are the brain and special sense organs of hearing and sight.

What kind of animals are fish? The fish are vertebrates which live in water and breathe by means of gills. They are usually covered with scales, and their limbs are in the form of fins. Most fish have an air bladder, which is a sac found in the upper part of the body. The bladder can be made larger or smaller to keep the density of the fish about the same as that of water. Changing the size of the bladder permits the fish to rise or sink. The bodies of fish are streamlined for easy motion through the water. The tail is the chief organ of locomotion, for the other fins are used chiefly for balancing.

What animals lead a double life? Because frogs and toads live part of their lives in water and part on land, they are given a class name, amphibian [ăm·fĭb′ĭ·ăn], which means double life. Other amphibians are lizard-like in appearance, and include the newts and salamanders. The amphibians develop in water, and during the early stages of their lives breathe by means of gills. In their adult stages they live on land, although they usually remain near water. The adults have lungs and a heart, consisting of three chambers. Except for a few tropical species, they all have four legs. They never

have scales. The mud puppies and salamanders have tails, while the frogs and toads do not.

Frogs and toads have short front legs, adapted to support their bodies, and long hind legs, used for leaping on land and swimming in water. The toes of frogs are webbed.

Frogs usually live in or near water, but toads may live anywhere on land, returning to the water only to lay eggs. The frog feeds in the daytime, but the toad feeds at night. Both eat insects which are caught by a long, sticky tongue fastened at the front of the mouth. The frog has teeth in the upper jaw, but the toad has none. The frog has a smooth skin, while the toad has a rough skin.

The males of both frogs and toads can croak. Most amphibian songs are given when the animals are at the water to lay eggs, although the tree frogs trill in the branches of trees all summer. The sounds are produced when air passes forcibly back and forth between the lungs and mouth and over the vocal cords. Air in the mouth is held in sound sacs located either on the side of the head or under the throat. These sacs expand greatly when filled with air.

What kinds of animals are the reptiles? Some of the reptiles are quite familiar. The snakes, turtles, lizards, crocodiles, and alligators are known at least by reputation to most of us. Reptiles are covered either with scales or with horny plates. They always breathe by means of lungs. When they have toes, the toes have claws. The reptiles on the earth today are not important compared to the giant reptiles of millions of years ago. In those days some could fly, some were huge and fierce land animals, and some lived in water. But reptiles could not adapt themselves to the changing environment, and few remain today.

A lizard has a long body supported upon four legs nearly equal in size, and generally has a brittle tail which is easily broken off. Some familiar lizards are the horned toad; the chameleon [kȧ·mē′lḗ·ŭn], which can change its color; and the Gila [hē′lȧ] monster. With the exception of the Gila monster, lizards are chiefly harmless, and are of value because they eat insects.

The snakes are the only land vertebrates which have no legs. Their ribs and the scales on their bodies permit them

to move forward on rough surfaces at a considerable speed. Except for a few poisonous varieties, snakes are beneficial animals, for they eat insects for food. The stories you hear about snakes milking cows, breathing poison, charming birds, and rolling like hoops are purely superstitions.

The turtles are protected by their hard shells, and as a result are slow-moving and awkward. Some turtles are vicious and for this reason should be treated with respect. Turtles have no teeth, but bite by means of a horny jaw.

Courtesy U. S. Bureau of Biological Survey

An animal born without normal color is an albino. This albino buffalo calf, abandoned by his mother, was nursed by a domestic cow and fed from a bottle.

The head of the crocodile is longer and more pointed at the snout than is that of the alligator, which has a broad head rounded at the snout. Otherwise they are rather similar in appearance and habits.

Most reptiles lay eggs, but a few bear their young alive.

What sort of animals are birds? Birds are animals with feathers. The legs of birds are scaly. The forelimbs are developed into wings which are used for flight by most birds.

The power of flight makes birds different in their habits from other animals. They can range over a larger area for food, and can protect themselves by escaping from their enemies. Their easy means of movement permits them to feed on the ground and to nest in trees. Flight makes possible the migration of birds, which makes them less dependent upon adaptation to cold than are the other vertebrates.

Some birds, however, are adapted to live throughout the year in one locality. These resident birds depend upon types of food available in winter as well as in summer. We see some birds which come north in summer, other birds which come south in winter, and still others only when they migrate in the spring or fall. Most of the familiar, insect-eating birds

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The bat and the mole both look somewhat like mice, but neither is a mouse. Bats catch insects in the air. Moles live underground and eat grubs.

are summer birds. The English sparrow, a seed-eating bird, is a resident bird, for it stays throughout the year. The Arctic tern is the champion traveler, for it migrates almost from pole to pole.

The beaks of birds are adapted in various ways to getting food. Modern birds do not have teeth, although some ancient birds did. The mouth opens into a food tube which widens out into a crop in which food is stored. The stomach of common pigeons and of some other birds consists of two parts: one of which secretes a digestive fluid, the other of which is a muscular gizzard filled with small pebbles used for grinding the food. Digestion is completed in the intestines.

All birds develop from eggs. Eggs commonly are incubated or kept warm by the female bird, although this is by no means always true.

What special adaptations have the mammals? The mammals are unusual in many ways. They include the most intelligent animals. Mammals are the only animals which have hair, and the only animals which produce milk to nourish the young. The young of most mammals are born alive and, in general, require the type of care which can be given by an animal of a fairly high degree of intelligence. Man, of course, is the highest type of mammal.

The variety of adaptations of mammals is rather amazing. The bats are adapted to flight, while the porpoises and whales are adapted to a life in water. Most mammals, however, are land animals.

The mammals which carry their young in pouches include the kangaroos and the opossums.

The animals which have claws include three very important groups—the meat eaters, the bats, and the rodents. Meat eaters have sharp teeth, small digestive systems, and are powerfully muscled for their size. Dogs, cats, bears, and weasels are typical of the meat eaters. The rodents include the gnawing animals with chisel-like teeth. The common rodents are squirrels, rats and mice, beavers, and rabbits.

The primates have nails instead of claws, and include monkeys and apes.

Another large group of mammals includes those animals with hoofs—pigs, deer, sheep, horses, oxen, and elephants.

You can readily see that these animals are adapted to different types of lives according to their structures. Claws are not so well adapted for running long distances as are hoofs. Hoofs are of little value for digging or for climbing trees. There are equally important differences in teeth, digestive systems, methods of adapting to warm and cold weather, and other matters essential for survival.

Exercise. *Complete the following sentences:* Fish, reptiles, and amphibians are —1— blooded. Animals with scales are —2— or —3—. Most vertebrates reproduce by means of —4—, the exception being the —5—, most of which bear their young alive. Animals with hair are —6—. Most vertebrates have four —7—. The only vertebrates with true wings are —8—. Turtles are members of the group called —9—. The word —10— means double life.

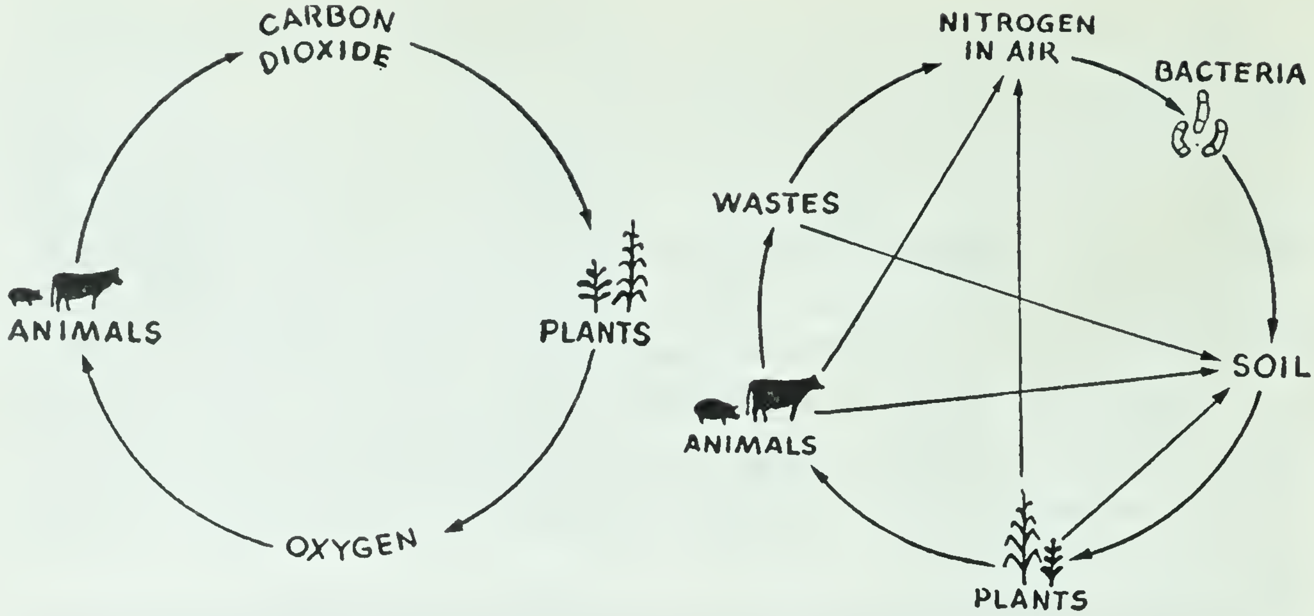
Science activities. 1) If a model of a dissected frog, fish, or rabbit is available, study its internal structure, and compare it with that of the honeybee.

2) When an animal such as a chicken or a rabbit is being prepared for the table, observe the internal organs, and identify as many as you can.

3) Make a zoo booklet, classifying animals according to groups listed in this problem.

9. How do living things depend upon each other?

In our everyday observation we have learned that living things do not exist alone nor separately in the neatly classified



The carbon and oxygen cycle (*left*) is much simpler than the nitrogen cycle. To help you understand the nitrogen cycle, look at the animals. Arrows indicate that they give off nitrogen through wastes and that when they die they give off nitrogen to the air or to the soil. Can you explain each arrow?

groups which we have just studied. In any community of living things there are many different kinds of plants and animals, each depending in many ways upon other organisms. Some animals depend upon plants for food, some upon other animals. In less obvious but just as important ways plants also depend upon animals for their food. Then too, maintaining the supply of air required by living things is dependent upon the different needs of plants and animals for gases in the atmosphere.

How is the supply of carbon and oxygen kept in circulation? In the relatively thin layers of soil and water and in the limited amounts of air in which living things must exist, there is but a small supply of materials necessary to maintain life. While we often think of the supply of oxygen and carbon dioxide in the air as limitless for practical needs, this idea is in error. Even the gases in the air are not free, but must be kept available by the work of living things.

You are familiar with the process by which plants make food. Carbon dioxide is absorbed from the air, and water is absorbed from the soil. In the process of photosynthesis, oxygen is released and passes out into the air. The carbon is stored in the various kinds of foods and structures of the plant.

When an animal eats food, the food is oxidized in its cells. As a result of this oxidation, the oxygen is no longer free but is combined with carbon. The carbon is thus released by animals from the plant and becomes part of the air.

The plant also uses some of its food to release energy, which keeps its protoplasm in motion and makes its tropisms possible. In the process some of the stored food is oxidized, and carbon dioxide is released. Bacteria which cause decay also release the carbon stored in plants, for one of the products of decay is carbon dioxide. About the only carbon which is permanently stored by living things is found in limestone and other similar rocks and in coal. All other carbon is kept in circulation.

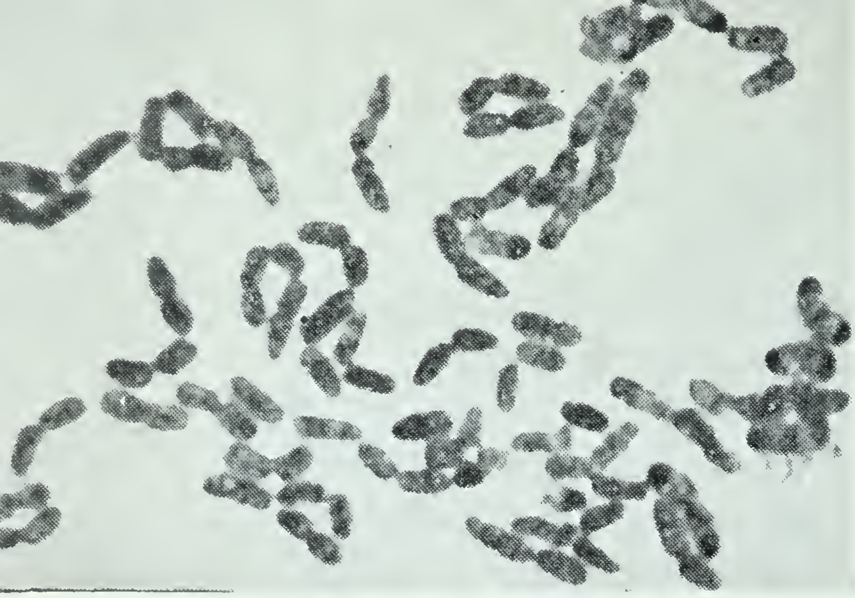
The supply of carbon dioxide in the air is so small that this constant renewal is important. It would not take many millions of years to use up the entire available supply if it could not be used over and over again in this way.

The changes just described are called the carbon dioxide-oxygen cycle, and may be represented by a circle as shown in the diagram on the opposite page.

How do living things use nitrogen? There is an abundant supply of free nitrogen in the air, but this nitrogen is of no use to the common plants and animals. They must take it directly or indirectly from the soil. There are few ways in which the supply of soil nitrogen is kept up. Some nitrogen is combined with oxygen in the air as a result of lightning discharges, and the resulting gas dissolves in rain water and enters the soil.

But the most important source of nitrogen from the air is that fixed in the soil by bacteria. These simple bacteria often live on the roots of the legumes—beans, peas, clovers, alfalfa, and locust trees—where they receive certain foods from the plants, and in return provide the supply of nitrogen so essential to this group of plants. Other nitrogen-fixing or nitrifying bacteria may live in the soil without the aid of the legumes.

The only source of protein foods (foods containing nitrogen) available to animals is plants. Although animals make more complex compounds of nitrogen than do plants, they still must obtain the raw materials indirectly from the soil.



© General Biological Supply House

These are some of the bacteria which live in the soil and fix nitrogen from the air in salts which are useful to green plants.

The nitrogen used by animals is returned to the soil in two ways. The animals give off nitrogen in their body wastes. These wastes enrich the soil to an important extent. Farmers recognize this fact when they use barnyard manure for fertilizer. Then when the animals die their bodies decompose, forming certain nitrogen compounds, and some of the materials thus formed enter the soil. But because nitrogen compounds are easily dissolved in water, the supply may be washed out of the soil. Then too, there are certain bacteria which break up the nitrogen compounds formed by animals and permit the nitrogen to pass back into the air. When plants die, the nitrogen they contain may similarly be released—either to the soil or the air.

The nitrogen cycle is much more complex than is the carbon dioxide-oxygen cycle. But it is just as important for life.

How do plants dwell together for mutual aid? If you are a good observer, you have noted the gray-green patches on rocks which are called lichens. Until about 50 years ago it was thought that they were single plants, but use of the microscope shows that they are colonies of algae and fungi living together. The fungi seem to absorb moisture which they release to the algae. The algae make food, some of which is used by the fungi. Both members of the partnership seem to be benefited, for the lichens grow where neither algae nor fungi can survive alone.

How do some animals live together for mutual aid? You are familiar with the complex social life of the bees and wasps. It is an interesting fact that many social insects belong to one order. In this order are also the ants. The ants have colonies in which all work together—some providing food, some caring for young, and some acting as soldiers.

Certain species of ants cannot do any work except fighting.

These ants capture other ants which are generally considered to be slaves. These slaves do the work of providing food and caring for the nest. Some soldier ants are so helpless that they cannot even feed themselves. Another group of ants cares for aphids, which give off honeydew. The ants of one species carry to the roots of corn plants the aphids which suck juices from the roots, injuring the plants. This removal of the juices may reduce the yield of corn and interfere with the food supply of animals which eat corn—man and his domesticated animals.

A story credited to Darwin and Huxley shows how many circumstances may be involved in one situation. Red-clover flowers are so deep that only bumblebees can pollinate them. But if there are many field mice about, the clover is not pollinated, for the mice eat the bumblebees by raiding their nests. However, if there are enough old maids in the community who own cats, the cats will eat the mice, thus insuring a good crop of clover seed.

Cheap seed increases the amount of clover planted, and causes a drop in the price of beef because there is plenty of clover to feed to cattle.

Are all relationships mutually helpful? You know that many bacteria are dependent upon living things for food. These parasites usually do nothing in return for the food they take, and if they are too numerous they may kill the plant or animal upon which they grow.

Saprophytes are somewhat useful, for they cause the release of carbon dioxide from dead plants which are keeping carbon out of circulation. Although saprophytes do cause food to spoil and useful materials to decay, nevertheless, in the whole community of living things, their work is essential for life to continue. For it must be remembered that no living thing owns the material of which it is made. Rather, it has merely borrowed the material for use, and must return it if life is to continue.

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* carbon dioxide, oxygen, nitrogen, air, legumes, manures, animals, plants, bacteria, food, decay, nitrifying. *Illustrate your paragraph by drawing in your notebook the two cycles discussed in this problem.*

Science activity. Set up as individual projects as many fresh-water aquaria as you can, using a variety of water plants and animals. In some, use fish; in others, insects; in others, crayfish; in still others, clams or leeches. Try to find a supply of plants which will live with the animals and provide them with oxygen. Do not forget that algae will provide considerable amounts of oxygen.

10. Why is there a constant struggle for survival?

You know already that any species of living things can produce many more offspring than can possibly survive. An interesting problem that you can work out for yourself is to figure how many offspring a pair of rats may produce in three years. Assume that all the young live, that half are males and that half are females, that the average litter numbers 10 young, and that the first young are born when the rats are six months old. Rats may bear four litters a year.

What is overproduction? One of the important means by which a species of any living thing maintains itself is by its ability to produce many offspring. Some common weeds bear thousands of seeds. A single plant may produce seeds enough to cover a city lot with plants if all the seeds grew. Insects produce hundreds of eggs. Even the mammals can produce many young. One cow may have six to ten calves in her lifetime. A pheasant hen lays perhaps 20 eggs every year. The female fresh-water perch (a fish) lays 100,000 eggs each spawning season. Practically every living thing is similarly capable of producing more offspring than can survive.

Because there is overproduction of all living things, they crowd and compete with one another in many ways. The most serious problem, of course, is that of finding a supply of food. Plants require a certain amount of space for their roots, and from the soil they take the water and minerals available. Soil simply does not contain enough minerals and water to support an unlimited number of plants. And in places where the soil is thin and dry, the amount available for plants is decidedly limited.

Even where the soil is rich and moist, there may exist such serious overcrowding of plants that there is not enough light to permit all plants to grow vigorously. Of the many seeds

Ewing Galloway photo

It may seem that lions kill because they are cruel. But the lion indirectly improves the animals on which it preys by eating those which are less able to escape. The lion kills, of course, to obtain food.

that may germinate, many will die before they mature because they are overshadowed by more vigorous or better-adapted competing plants.

There is a similar overcrowding of animals. If in a given area all the rats born as offspring of one pair should survive, the resulting rat population would soon overrun the land. In some tropical islands rats have been introduced by accident where they had no enemies to keep them in check. First the rats ate the best food available—birds' eggs, young, tender plants, and shellfish that they found at low tide. The lack of birds gave insects an opportunity to multiply, and the amount of plant growth was decreased. As the rats became more numerous, they began to eat the larger plants. The larger animals died from lack of food, and the rats ate their bodies. Finally the rats ate everything that was fit to eat, and turned

on each other. They soon starved, and the soil eroded. What once was a pleasant land at last became desolate waste.

This illustration is but slightly more extreme than many others that might be chosen. The importation of rabbits in Australia caused a large part of the continent to be overrun by the pests. Hundreds of thousands of dollars are spent in fighting them annually—by building rabbit-proof fences and by poisoning them. Foxes were introduced to help control the rabbits, but the new environment proved so favorable for the foxes that they became large and fierce enough to kill and eat sheep. Watercress, which is a harmless plant in England, choked streams until boats could not navigate them in Australia.

In Bohemia, a state of middle Europe, four Canadian muskrats were introduced. There they increased in number and size until they are now pests. They dig tunnels in dams and banks of ponds, which are used for growing fish. They eat river crabs and mussels (a mollusk used for food by man). They go onto the land to eat grain and vegetables.

These examples are but a few of the many that show what happens when the balance of nature is upset by overproduction. Natural conditions eventually restore any upset of balance in one of several ways.

How is a natural balance maintained? Under natural conditions every living thing has its enemies. These enemies may be larger animals or they may be parasites and disease bacteria.

The smaller animals—the rodents, the birds, and even the insects—are kept in check because they provide food for larger animals. Whenever their number increases, they provide an increased supply of food for the animals which naturally eat them. These animals, called predators, increase in number and reduce the population of small animals.

Another important factor in reducing numbers is disease. When animals are few in number, they stay far enough apart that the probability of infection is decreased. But when they live crowded together, the ticks, mites, and lice which carry disease can more easily pass from one animal to another. The catching of disease by direct contact is also more probable when animals are crowded. The increase in number of

Courtesy National Association of Audubon Societies

Not all living things are adapted to changing environments. This famous picture of the passenger pigeon shows these beautiful birds as they were painted long ago by Audubon. Today there is not a living passenger pigeon in the world.

grouse, rabbits, and some other small animals proceeds in a regular manner, until finally they become seriously over-crowded. Then within a single year the population will drop to less than one-tenth of what it was. This change in the number of small animals is so regular in occurrence that game wardens can predict it quite accurately in some sections of the country.

A third and perhaps most important factor limiting the number of survivors is the lack of food. When deer become too crowded in a forest, they eat leaves from trees and shrubs

as far as they can reach. Young deer, or fawns, are unable to reach enough leaves for food when they no longer take their mothers' milk. They either die or grow up lacking in strength and vitality.

A fourth factor in keeping down populations is rate of reproduction. Only healthy and well-fed animals reproduce at a normal rate. When disease and a decreasing food supply reduce vitality, fewer young are produced, and the species tends to decline in number. This rule has been tested experimentally on fruit flies (sometimes called vinegar gnats) and is observed to apply to rats and domestic cattle.

What is "survival of the fittest"? Among all types of animals there are differences of many kinds. These differences between individuals of the same species are called *variations.* Some animals are stronger than others, some more able to resist disease, some more capable of finding food, some more clever in escaping enemies. Some plants are able to send their roots deeper into the soil, some to climb higher to reach light, some to produce thicker foliage to shade competing plants.

In any given environment some individuals are better fitted to survive than others as a result of these variations. As is natural, these are the individuals that produce the most offspring and, as a result, their qualities are passed on to their offspring. Over a long period of time considerable changes may take place in a species. For example, all wild horses in the western United States are descendants of horses brought by the Spaniards. These horses were Arabian stock —tall, slender, and swift. But as a result of selection, their descendants are shorter, stockier, and tougher in ability to withstand cold and lack of food. The Indian pony weighs several hundred pounds less than its Arabian ancestors.

This natural selection of individuals results eventually in survival of the fittest.

Exercise. *Make a table by ruling your paper into four columns. Head the columns as follows:* PLANT OR ANIMAL, NATURAL FOOD, NATURAL ENEMIES, USUAL ENVIRONMENT. *Using all information you can find in this entire unit, complete the table by listing 15 animals and 10 plants in the first column, and other information in the other columns.*

Science activities. 1) In a large, flat box put sand in one corner, sawdust in another, soil in another, and stones in another. Count out 100 radish seeds and scatter them over the box. Keep the box moistened, and at the end of a week and of two weeks count the number of surviving plants.

2) In a flowerpot filled with rich soil put bean seeds as thick as they will lie in a single layer, and cover them with a half-inch of soil. Keep them watered well, and observe what happens. Keep a record of the number of seeds used, and the number of plants surviving.

11. How are living things protected from their enemies?

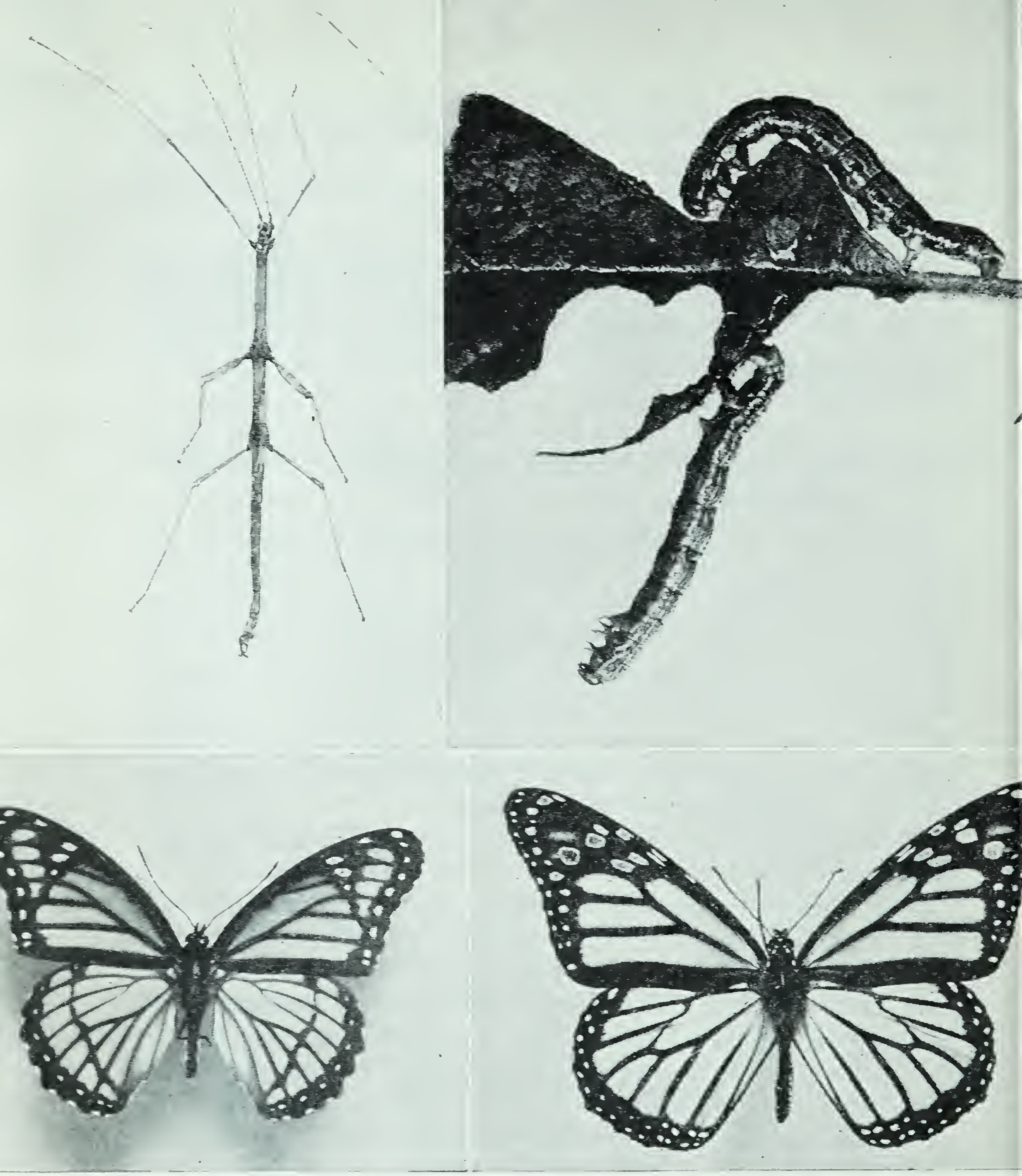
Since every living organism must eat, most living things are in constant danger of being eaten. For the enemies of most living things are those other living things which depend upon them for food. Other enemies are chiefly those which compete for the same food—that is, a jackal and a hyena may want to eat the carcass of the same zebra after it has been left by a lion. If the jackal and hyena fight, it is to obtain food. Animals may also fight to obtain mates. Queen bees fight for the right to live in the colony.

Plants and animals are protected by special structures or by special behavior or by both.

How does color protect animals? Some animals are colored so much like their surroundings that it is difficult to see them. Most birds are rather dull colored, darker above than beneath, with the color along the sides shading from dark above to light below. This is called counter shading. The same type of coloration is seen in fish, for many fish are dark olive color above and whitish beneath. When fish are seen from above, they look like the bottom of the stream or lake; but when seen from below, they blend into the white light from above.

The walking stick is an insect that resembles its surroundings not only in color but in shape as well. It has long, slender legs and feelers, and looks so much like a twig that the difference is difficult to see. The walking stick remains motionless most of the time. It is a relative of the grasshopper.

Some animals imitate other animals or part of a plant in



Courtesy U. S. Bureau of Entomology and Plant Quarantine

Three of these four animals—the walking stick (*top left*), the measuring worm (*top right*), and the viceroy butterfly (*bottom left*)—are fakes, seeming to be that which they are not. The monarch butterfly (without bars on the wings) is protected by bad taste. An animal which has learned by experience not to eat the monarch will not eat the viceroy. But if the wings of the viceroy are removed, the animal will then eat it.

color or shape. This type of imitation is called mimicry. Many flies mimic bees or wasps, which are well defended by their stings. Some beetles and moths are also similar to wasps in appearance, which is confusing to their natural enemies, besides making it difficult for us to distinguish them.

The monarch butterfly is distasteful to birds, and is not eaten by them. But the viceroy butterfly does not have an objectionable taste. The viceroy is so similar in appearance to the monarch that birds often fail to eat the viceroy because they mistake it for the monarch. The dead-leaf butterfly looks much like a dead leaf when at rest. Its wing veining mimics the veining of leaves, the edges of the wings look like the margins of leaves, and there are even two transparent spots which give the appearance of holes eaten in the leaf by insects.

Some animals change color with the seasons. In the far north the fur of many animals is white in winter, but becomes brown in the summer. The hare, fox, lemming, and weasel blend with the white snow in winter and with the brown earth in the summer because they grow two coats of fur a year. Similarly the ptarmigan [tär′mĭ·găn, a bird which lives high in the Rocky Mountains], changes its color with the seasons.

The chameleon can change its color quickly. Its surroundings and its state of rest or excitement cause the change. This animal, which naturally lives in the tropics, may be bright green or grayish brown. One kind of chameleon is a favorite animal for a pet. Many of them are sold at circuses and fairs.

How are colors used for warning? There are some animals which have no need for concealment, for other animals know from experience that they are unpleasant or disagreeable or dangerous. Many caterpillars which have a disagreeable taste are brightly colored, apparently to serve as a warning to birds to avoid them. Another conspicuously marked animal is the skunk, for the white stripes down the back contrast sharply with the black fur. The skunk is well protected by the disagreeable odor of the liquid which it gives off when in danger of attack.

The conspicuous color of wasps serves the same purpose. The only protection these insects need is to make their presence known, for few animals care to risk their vicious sting.

L. W. Brownell photo

The Gila [hē′ lȧ] monster is the only poisonous lizard in the United States. Its skin looks as if it were made of brilliant beadwork, serving as a warning coloration.

How are other animals protected from their enemies? There are many methods of defense used by animals against their enemies. The stings of the wasps, bees, and bumblebees are hollow tubes, needle sharp, which are used when necessary to inject a poison into the flesh of the enemy. The honeybee can sting only once, but the bumblebee and wasp can sting again and again.

Four snakes commonly found in the United States are poisonous. These are the rattlesnake, the copperhead, the moccasin, and the coral snake. The fangs of these snakes are hollow and, as they strike, pressure upon the poison sacs causes the poison to be injected into the wound caused by the bite. The bites of these snakes are frequently fatal.

The catfish or horned pout possesses sharp spines capable of inflicting a severe wound on any enemy attacking it.

The porcupine is covered with sharp, barbed quills, which come out easily. When attacked by an enemy, it rolls up into a ball. If an enemy is so rash as to attack this ball, its mouth is pierced by the quills which work their way into the flesh. Porcupines cannot shoot out their quills at the enemy.

Some fish can give an electric shock to enemies attacking them. In this group are found the torpedo, the electric catfish, the electric eel, and the stargazer. The torpedo has on each side of the head a large structure which serves as a battery to give a shock when touched.

Other animals have a hard external shell which protects the soft parts within. Turtles can withdraw the greater part of their heads and legs within their shells. The armadillo, which lives in the South, is a mammal which is provided with bony movable shields. When disturbed, it rolls up into a ball, exposing these hard shields on every side.

Courtesy U. S. Fish and Wildlife Service

The snapping turtle has two effective defenses: a hard shell and the ability to bite viciously. Its disposition matches its ugly appearance.

Some animals pretend to be dead when attacked by their enemies. They remain quiet until an opportunity of escaping presents itself. This kind of behavior is so typical of the opossum found in the southern states that the expression "playing possum" has become a part of our language. The hog-nosed snake, which lives in sandy places east of the Rocky Mountains, also pretends death as a means of protection.

Of a somewhat similar nature are the means taken by the ruffed grouse to protect its young. The nest is located on the ground. When an enemy approaches the nest, the mother pretends to have a broken wing, and drags herself a little way ahead of the enemy. When it has been led to a safe distance from the nest, the mother suddenly flies away.

What other means of protection do animals have? You know that many animals can fight so well that they have little need of other defense. Tigers, eagles, and weasels are rarely attacked by enemies. Other animals which are practically without means of defense are so clever at fleeing that they need not fight. Most birds can flee their enemies. The sparrow flies quickly out of reach of the cat; the pheasant runs from the fox; and the duck swims away from the hungry wolf. In fact flight is a means of defense almost as common as concealment.

How are plants protected? Plants as well as animals have ways of protecting themselves. The chief enemies of plants are animals and such unfavorable weather conditions as ex-

treme heat and cold and drought. The bark of trees and shrubs with its tough layer of cork keeps the rain from the stem and prevents evaporation. Plants are protected from animals by prickles and thorns, as is the case of the cactus and thistles. Some plants have a disagreeable taste or odor which protects them from being eaten by animals. Some plants are poisonous.

Filmstrip: How animals protect themselves. Pickwell.

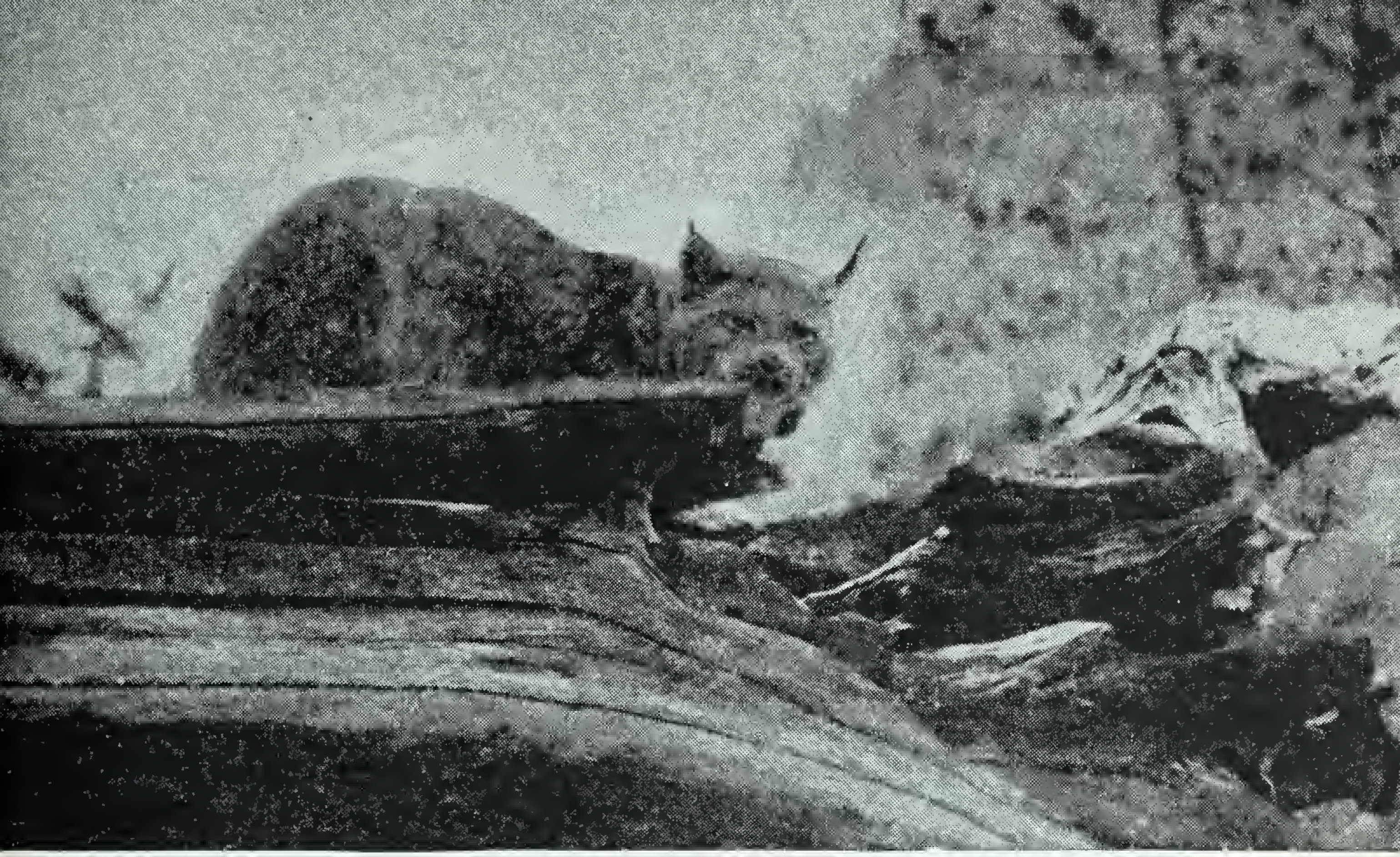
Exercise. *Complete the following sentences:* Turtles are protected by a —1—. Wasps possess —2— as a means of protection. Counter —3— is a kind of protective resemblance. Resemblance of one animal to another for protective purposes is called —4—. The walking stick resembles a twig in both color and —5—. During the winter the color of the ptarmigan is —6—. The —7— is able to change its color quickly. The white stripes on the skunk are examples of —8— colors. The rattlesnake can eject a deadly —9— through its fangs. The cactus plant has very small —10—.

Science activity. Paint two potatoes almost white on one side, blending the paint so that it gradually fades into brown, leaving one half wholly brown. Use another unpainted potato for comparison. Run stiff wires through all three potatoes. Put the light side of one painted potato underneath, and the light side of the other painted potato above. Place all three in a bare spot. Support them by sticking the wires in the soil, and observe them from a distance.

12. How do plants and animals live together in communities?

A community of living things is found in a region of sufficient size to support many forms of life, and consisting of the same conditions of soil, moisture, and climate throughout its area. One type of community may blend into another, and some animals may live at times in more than one community. Within a community the relationship of the various organisms is close. If the community exists for more than a few months, there must be a fairly good balance of plants and animals.

What is a typical forest community? A typical forest community of the northeastern section of the United States



L. W. Brownell photo

The lynx, or bobcat, is a common dweller of the northern forests. It eats a variety of small animals. It looks somewhat like a large housecat except for the hairs on its ears.

is complex in its make-up. The most conspicuous part of the community, of course, is the trees, and this is the only part the careless observer sees. The typical forest may contain many different combinations of trees, depending upon soil and moisture conditions. But there are usually oak, maple, elm, beech, and basswood trees in an upland forest. Sometimes hickories or butternuts are found. Growing partly in the shade of these taller trees are shrubs of many kinds, one of the interesting ones being the hazel bush, which bears nuts. There is a variety of low-growing plants, some of which bear attractive flowers.

The more common flowering plants include the moccasin flowers, larkspurs, trilliums, violets, jack-in-in-the-pulpits, and the false rue anemone. Some flowering plants bear berries in the autumn, a few of the commoner ones being the bunchberry, blueberry, and the twisted stalk. In the shady places where a moist, sandy soil is found there may be ferns of various kinds.

When one has observed all life on the surface of the soil he still has not come to the end of living things, for the soil

contains millions of bacteria—perhaps as many as a billion per gallon of soil. Worms and insect larva abound in the rich humus soil of the forest.

The animal life of the forest is not easy to discover, for most animals are shy and protected by keen ears and noses. There are many members of the squirrel family in the forest. Red and gray squirrels live there, but not in the same neighborhood.

Along the edge of the forest may be found the chipmunks. These lively, striped animals live in burrows but come out during the daytime in search of food. They eat acorns and beechnuts and seeds of grass and ragweed plants. They may eat wild strawberries in the summer and wintergreen berries in the autumn. They sometimes turn to a meat diet consisting of grubs of May beetles, frogs, and small snakes. Occasionally they eat the eggs of birds.

Many mice live in forests, depending upon weed seeds, nuts, maple seeds, and insects for food. They store seeds for use during the winter, choosing a hollow in the ground or in a log for a hiding place for their food.

The insects of the forest are of several varieties, the commonest being beetles of various kinds, wasps and bees, some varieties of ants, and a few species of butterflies and moths.

The birds of the forest can be heard but are not easy to see. There are always woodpeckers and warblers in forests. Woodpeckers drill beneath the bark for insects, while warblers pick insects from the leaves and bark. The brown thrashers scratch among the leaves to find beetles and crickets. Other birds which may be seen by the watchful observer are the scarlet tanagers, the vireos, the jays, and the nuthatches. Among the birds of prey are the hawks and owls, which eat small animals—mice, squirrels, and chipmunks. The shrikes eat mice, birds, and insects. They impale their prey on thorns or barbed wire fences to assist in holding it while they tear it to pieces.

Ranging the woods are the larger mammals. The deer eat the leaves of shrubs and trees. Preying upon the rabbits, deer, and other larger animals are the foxes and wolves. The foxes eat birds, reptiles, and fruit, as well as small mammals. And occasionally there ambles into the woodland

L. W. Brownell photo

The flowers of the pitcher plant grow from the cluster of pitcher-shaped leaves at the base. Explain how each leaf serves as a trap for insects.

scene a brown bear, depending upon fruits, insects, and small animals if nothing better is found, but taking deer if they are available.

What is a typical orchard community? Compared to the natural forest community, the man-made orchard community is simple. The fruit trees and the clovers and grasses growing beneath the trees make up most of the plants. The bees pollinate the flowers in the spring and take the nectar to make honey for food. The clovers provide nectar later in the season.

There will naturally be a number of insect-eating birds in the orchard. But man simplifies the environment of the orchard still further by use of poisonous sprays which kill many of the insects which would naturally live on the leaves and fruit of the trees. If left alone, codling moths survive to

lay their eggs in apple blossoms; tent caterpillars spin their webs on the leaves and devour them; and many other insects—flies, ants, wasps, and butterflies—make their homes among the trees and grasses.

What is a typical swamp and bog community? A swamp is a region in which areas of spongy land and open water are more or less intermixed; while a bog is more likely to be made up of little elevations called hummocks, and more often than not is shaded by occasional trees. Common trees growing in bogs are tamaracks and black ashes. The lower-growing plants in both places are grasses and sedges, which grow with their roots in the water or in the rich soil just above the water line. The soil of swamps and bogs is largely formed from decaying vegetation and silt washed in by rains. This soil is saturated with water. Growing on the hummocks are found many beautiful flowers, but they are often almost buried from sight by the competing grasses. The marsh marigold, the wild calla, the swamp candle, the violet, and the skunk cabbage are commonly found near or in bogs. Out in the shallow water of the swamp grow the familiar cattails. A tall, rough plant called joe-pye weed grows along the borders of the swamp. In bogs shaded by trees a variety of ferns may be found.

An interesting group of bog plants catches insects. The pitcher plant has pitcher-like leaves which hold water. Insects entering the leaf pitcher cannot escape because of the bristles inside the hollow leaf, and there they die, to be absorbed by the plant. The sundew and Venus's-flytrap catch insects by enfolding them in their leaves. The insect-catching tropisms of these plants are perhaps the most complex type of behavior found in plants. All these plants catch insects because the waters of the bog are not rich in nitrogen salts needed for their growth. The insects supply the needed food.

The birds of bog and swamplands are numerous and interesting. The red-winged blackbirds nest in reeds and eat seeds and insects. There are wading birds which walk through the shallow waters on their long legs, reaching down to the bottom of the swamp with their long necks and beaks to catch insects and small mollusks. Ducks make their nests on the hummocks, and swim about on the water in comparative

Although the swamp looks lifeless, the many moundlike muskrat houses show that beneath the water and in the tangled vegetation many living things make their homes.

safety. Mallards feed in water shallow enough to reach bottom by tipping up, while other ducks feed further out by diving into the deeper water for food.

Muskrats build their houses in the shallow water, using straw, roots, stems, and mud to form a conical mound, inside of which they leave a chamber for living room. Their food consists chiefly of roots and stems of water plants, some of which they store for use in the winter. They also eat fresh-water clams and an occasional fish. Muskrats are quite safe from most enemies, for they swim easily for hours.

Mice run about on the matted grasses of the swamp and build curious nests of grass and down.

The minks are the most deadly hunters of the swamp animals, for they capture muskrats, birds, mice, and any small animals they can find. Minks are powerful fighters, and can kill animals much larger than themselves. They belong to the weasel family.

There are many other inhabitants of the bogs and swamps —turtles, water snakes, frogs, and fish. Each must protect itself from its enemies while obtaining food. The snapping turtles eat young ducks, but the skunks eat the eggs of the

turtles which are laid on land. Every animal has its enemy, and every plant is possible food for some animal. It is in the swamps that the huge moose chooses to feed on tender grasses and water plants.

What are some other communities? There are many communities. Ponds offer an assortment of life different in many respects from that of bogs and swamps. Forests of the type found on dry ground differ from forests found along rivers and lakes. The desert community is entirely different from the moist-region community.

Communities do not always remain the same. A pond community after a period of dry years may become a swamp or even a dry-land community, with new plants and animals appearing as the climate changes. Then when wet weather returns, the pond community may gradually re-establish itself. A fire passing through a forest community changes it entirely, for the plants which grow up following the fire are not the same as those which lived in the forest before.

Filmstrip: Forest botany. Spencer.

Exercise. *Complete the following sentences:* A community is a region of similar conditions of —1—, —2—, and —3—. It must contain a variety of plants and animals in fairly good —4—. These animals include those which eat —5— and others which eat —6—. There are —7— and larvae of insects in the soil. Man upsets the —8— of communities by removing some species and introducing others. Communities change as the —9— changes or when some unusual occurrence, such as a —10—, changes conditions of life.

Science activity. Prepare a report on one of the other types of communities mentioned briefly in this problem. Consider a farm wood lot or a city dump as a community if you cannot study any larger area.

A Review of the Unit

Animals are adapted for survival by possession of structures and types of behavior suited to the environment in which they

live. They solve their life problems in many different ways, but all have the same problems of reproduction, food-getting, metabolism, movement, and defense.

The structures of plants and animals vary around a few basic plans. Plants or animals which are similar in most respects are classified together. The basis of classification is structure.

Living things cannot exist alone, for they depend upon each other for food and air. Nor can they exist when there is too much competition for food, space, and other needs. The greatest good results when a community of living things is in balance—that is, when various kinds of plants and animals live in numbers sufficient that many members of each species can survive, and no species exists in numbers sufficient to destroy its own food supply.

An exercise in thinking

Match the principles and related ideas, according to the directions given in the review at the end of Unit I.

List of principles

A. Life is a series of chemical changes that take place in protoplasm.

B. Structure of an organism determines in what environment it must live.

C. Environment determines what types of living things eventually survive.

D. Every living thing is dependent in many ways upon other living things.

E. Osmosis is the exchange of liquids of differing densities through a porous membrane.

F. All living things are able to respond to stimuli in the environment.

G. All living things are able to use food to provide energy.

H. All living things are able to move to carry on their life functions.

I. Growth is an increase in size or in complexity or parts of an organism.

J. All living things start life from a one-celled stage.

List of related ideas

1. Algae absorb water containing minerals through their cell walls.
2. Metabolism includes the process of breaking down food to release energy in the cells.

3. Algae increase in number by cell division.

4. When a continent sinks beneath the sea, all life on it becomes extinct.

5. Animals give off carbon dioxide which is used by plants.

6. In order to get light, grapevines must be supported by their twining tendrils.

7. Plants give off carbon dioxide when they use the food they make.

8. Many reptiles which once required a warm climate are now extinct.

9. An adult insect has many parts not found on the larva.

10. There is a constant streaming motion in protoplasm.

11. Animals require nitrogen compounds to build protoplasm.

12. Water passes from leaf veins through the cell walls into the cells.

13. A plant which lives on decaying organic matter is a saprophyte.

14. Nest-building is instinctive with most birds.

15. Fertilization brings together the two cells which start new organisms.

16. Most insects have the power of flight.

17. Larger organisms grow by cell division.

18. Leaves of plants often turn to follow the sun.

19. Energy obtained from the sun is released by oxidation of food in the tissues.

20. The unit in which protoplasm carries on life functions is the cell.

21. Water enters root hairs from the soil.

22. A lichen consists of two plants living together.

23. A plant usually weighs thousands of times more than the seed from which it forms.

24. Photosynthesis is the process of manufacturing food by green plants.

25. Fish have an air bladder and fins to maintain their position in the water.

26. In an egg there is a single fertilized cell which is alive.

27. The turning of a vine stem around a support is a tropism.

28. One-celled plants increase in size after they are formed by cell division.

29. Materials found in living things are not the same compounds that are used for food.

30. Plants seek water by extending their roots down into the soil.

31. As a pond dries up, organisms which lived there disappear and new organisms appear.

32. Instincts of insects are highly developed.

33. A ground squirrel has claws adapted for digging burrows.

34. Root hairs contain a sirupy sap, denser than water.

35. Bacteria and molds do useful work in causing decay.

36. A change in the amount of vegetable matter in the soil causes a change in the type of plants growing there.

37. Coloring which helps an animal to hide is called protective coloring.

38. Food must be digested before it can be used.

39. Some young birds do not have feathers.

40. All animals finally depend upon green plants for food.

Some things to explain

1. Why do insects occupy such a prominent place among living things?

2. Why is it sometimes difficult to determine whether a certain organism is a plant or an animal?

3. How does all life depend on the work of chlorophyll?

4. Explain how some common plant or animal not mentioned in the text is adapted to its environment.

5. Explain how some plant or animal is dependent on other living things.

6. What advantages does the possession of a backbone give an animal over one that does not have a backbone?

Some good books to read

The Book of Birds, The Book of Wild Flowers, National Geographic Society

Buck, Frank and Ferrin, Fraser, *On Jungle Trails*

Compton's Pictured Encyclopedia

Comstock, Anna B., *Handbook of Nature Study*

Dougan, L. M., *Stories of Outdoor Science*

Durand, Herbert, *Field Book of Common Ferns*

Fabre, Joan H., *Insect Adventures*

Hoogstraal, H., *Insects and Their Stories*

Jones, J. E., *Some Familiar Wild Flowers*

Krieger, L. C., *The Mushroom Handbook*

Lydekker, B., *Wild Life of the World*

Mann, P. B. and Hastings, G. T., *Out of Doors*

Mosely, E. L., *Trees, Birds and Stars*

Nelson, E. W., *Wild Animals of North America*

Picture by Dr. W. J. Breckenridge

This ruffed grouse is "drumming" by beating his wings on a hollow log in order to attract a mate. Many kinds of male birds court mates.

Pope, C., *Snakes Alive and How They Live*
Trafton, Gilbert H., *Bird Friends*
Verrill, A. H. *Strange Birds and Their Stories*
Wood, Clarence, M., *Insect Ways*

Some interesting motion pictures

Bees, Wasps, Ants and Allies. Instructional Films *(16 silent)*
Beetles, Butterflies and Moths. Instructional Films *(16 silent)*
Frogs and Toads. Instructional Films *(16 silent)*

The Green Plant. Eastman *(16 silent)*
Interdependence of Pond Life. Gaumont British *(16 sound)*
Leaves. Erpi *(16 sound)*
Living World. Carter *(16 silent)*
Marine Life. Visual Education Society *(16 silent)*
Plant Growth. Erpi *(16 sound)*
Plant Magic. Visual Education Society *(16 silent)*
Plant Roots. Erpi *(16 sound)*
Plant Traps. Erpi *(16 sound)*

Some related lantern slides

Living Things—Animals. Keystone View Co.
Living Things—Plants. Keystone View Co.

Courtesy Birmingham Chamber of Commerce

UNIT THREE

HOW DO WE CONTROL MATTER AND ENERGY?

THE HISTORY of civilization has largely been the story of man's control of matter and energy. It is almost certain that man's first slow progress came when he learned to control fire to keep warm, to make possible living in colder climates, and to cook food. Then he learned to use the first crude tools and weapons to apply his own energy more efficiently. Many thousands of years later he learned to save energy by using a rolling wheel for moving heavy loads instead of lifting or dragging them. Finally complex machines were invented, and natural forces were harnessed.

Today our machines do such amazing things that the fairy stories of ancient peoples no longer seem marvelous. We fly; we take precious metals from rocks; we bring the energy of the sun through wires hundreds of miles to banish the darkness. The commonplace things in your home would have seemed the blackest magic a hundred years ago.

Yet we are not magicians. We have learned some very difficult and yet simple things. We have learned a little about what matter is. We can describe and measure changes in energy. We control some of the forces of nature and protect ourselves from the rest. We change useless rocks, plants, and gases into the things that make up our homes, provide our food, and light our roads. We have knowledge of chemicals and of how they can be made into useful products.

As a result of our control of matter and energy, we live in better houses and eat better prepared, more wholesome foods than any of our ancestors ever enjoyed. We work shorter hours at easier work than they did. We enjoy amusements of which they did not dream. In spite of all the improved living conditions which we enjoy, the end of the improvement is not yet in sight.

We now make so many new products each year that no one person can know what they are and for what they are used. Still we know that our civilization is not the best that can be developed. We do not have more than a fraction of the knowledge that may sometime be gained. Yet we have used our knowledge so well and have changed living conditions so rapidly that no person of a past age could imagine the things we call commonplace.

Courtesy Jones and Laughlin Steel Corporation

Matter occupies space. This sheet of hot steel has been rolled from a bar, but the change in form does not change the amount of matter in the metal.

1. What is matter?

It is said that men rarely realize during their own lifetimes what the really important discoveries of their generation are. It is likely that this is the case today. For while people read of wars, elections, and sports, many scientists are smashing atoms, studying cosmic rays, and doing other important work in their laboratories. It is not surprising that the greatest scientists of the world are devoting their time to studying matter, for when we understand it better, we can control its use better than we now do, and perhaps discover new ways of living that will make our present machines look as out of date as ox carts do today.

How can we recognize matter? Because we are made of matter, because matter is all around us, because it is the stuff of which the universe is made, it seems that it should be simple to define matter. But there really is no good definition for it. The best we can do is to describe it and to tell as far as we know of what it is made.

The most noticeable thing about matter is that it occupies space. We recognize most common things, at least in part, by their differences in size—in other words, by the amount of space they occupy. No one would mistake a rat for a horse. Some forms of matter occupy a definite amount of space; other forms change in the amount of space occupied.

Matter has mass. *Mass* is the amount of matter in a thing or object. When we weigh anything, we measure the pull of the earth upon the mass of that object. When you step upon the scales, the pull of gravity causes the platform to move

down, compressing the springs and moving a needle. But your weight does not show how much mass there is in your body, except as it is affected by gravity. If you should climb a very high mountain, you would lose weight not only from the exercise but also from getting farther away from the center of gravity of the earth. If you could get on the moon, your weight would decrease to one-sixth of what it is on earth.

Thus we see that the amount of matter in an object is different from weight. Your mass, or that of any object, at any time or place, is always the same; but the weight depends upon gravity, which varies from place to place.

The resistance of matter to being set into motion or, if it is in motion, its resistance to being stopped is also dependent upon mass. This property of matter is called inertia [in·ûr′shȧ].

Some matter is elastic—that is, it will return to its original shape to some extent after it has been pressed or squeezed out of shape. Some matter can be changed in shape by pressing or molding it. Each kind of matter has some special properties in which it differs from other matter. Hardness, color, and ability to carry heat are properties which we use to recognize different kinds of common matter.

Of what is matter made? You might think that matter is not made of anything—it is just matter, and that is all there is to it. But that is not all there is to it by any means. There are hundreds of brilliant men trying to learn what matter is, and their knowledge is far from complete.

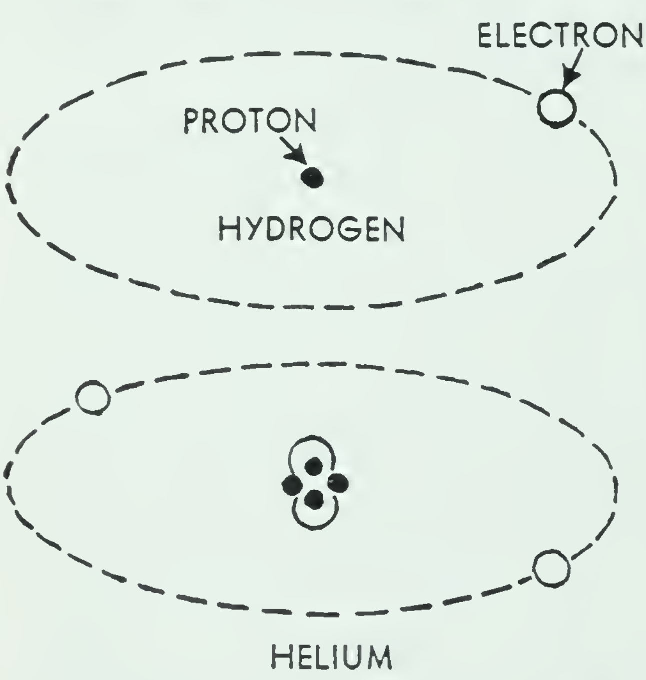
If we divide any common compound into the smallest possible parts, you know that each part is called a molecule. That is, if we take the tiniest possible amount of water, that particle is a molecule of water. If we divide the molecule of water further, it is no longer water. The particles broken from the water molecules are *atoms* of hydrogen and oxygen.

It was once thought that the atom was a tiny block of matter, like a grain of sand but much smaller. The word atom means uncut. Scientists said that matter could not be created or destroyed under any circumstances—that it was unchanging and would last forever. Under ordinary circumstances this is true. But scientists have found some extraordinary circumstances in which matter is broken up completely.

An experiment used to show that matter could not be created or destroyed is worth our study. Some common material, such as a piece of coal, was sealed into a jar with oxygen. The sealed jar was then weighed, and the coal set on fire by an electric spark. After the burning was complete, no coal was left, but the weight of the jar and the contents was exactly the same after burning as before. Burning, as you know, is a chemical change, and chemical changes do not destroy matter.

After perfecting such experiments, scientists were quite certain that matter was unchangeable. But then Madame Curie discovered radium. Radium gave off strange rays strong enough to expose a photographic film in a darkroom —rays which were turned aside by magnets. As radium gave off rays, it lost weight. The radium was destroying itself! The scientists of the world were startled to find their best theories upset.

This discovery of radium verified earlier observations of another scientist and opened up a completely new field for experimenters. They set out to discover what materials are found in an atom. It seems that an atom of hydrogen, which is the simplest atom, is made up of two particles: an electron which revolves around a proton. There is a large amount of space inside the apparently solid atom. It is estimated that the proton is about 1840 times as heavy as the electron. If a free proton is attracted by a magnet, it moves toward the south, or minus, pole; while a free electron moves toward the north, or plus, pole. Thus we see that these parts of the atom seem to be charges of electricity.



The hydrogen atom (*top*) is the simplest atom that exists in a balanced state. The helium atom consists of four times as much matter as does the hydrogen atom. Note that two of the electrons are in the center of the helium atom. The black dots represent protons.

A molecule of helium, which is next to the lightest gas in

weight, has in its center four protons and two electrons, with two electrons revolving around the outside. The atoms of other elements are much more complex than these two, but all are made of the same units of energy. There are other particles of which little is known which may also be found to be part of an atom when studied more fully.

One of the difficult things to understand is how a small electron separated from a small proton by a considerable space can seem solid. To help understand why they appear solid, you might think of the following game. One boy has on a string a ball which he whirls around his head. Another boy tries to touch the head of the first boy without getting hit by the ball. If the ball is whirled slowly, it can be done. If, however, the ball could be whirled at a rate of 5000 turns a second, it would be impossible for the second boy to get his hand inside the circle. The moving ball would seem the same as a solid circle.

Courtesy Massachusetts Institute of Technology

This illustration shows the discharge of electrical energy from one of the first atom smashers. Discoveries made of the nature of the atom led to further experiments which resulted in the development and use of atomic energy.

The atom is so small that it is estimated that perhaps two quadrillion (2 followed by 15 zeros) can be placed inside the space the size of a pinhead. Inside the tiny atom the still smaller electron moves at a rate of thousands of miles a second. Is it any wonder that the atom seems solid?

Is matter really energy? Instead of matter being made up of solid particles, it seems that we have in the atom only flying charges of energy — the protons and some electrons tightly packed inside the atom as a nucleus, and other elec-

This is the way the apparatus is arranged for the demonstration.

trons moving around them at a great rate of speed.

It is difficult to think of your knife blade as being made up mostly of space and of energy. The steel of a knife seems too solid to be broken into anything else. Yet scientists have succeeded in removing electrons from a great number of things. To the best of our knowledge today, we must say that matter is made up of particles of energy.

Most of our knowledge of the atom has come from taking it apart. In the early 1930's atom smashers, like the one shown on page 107, were used to accomplish this. Each kind of atom is made up of a definite number of electrons, protons, and neutrons (neutral particles). The center (or nucleus) of most atoms contains many particles closely packed and held together by tremendous forces.

Recently it has been found that the heaviest atoms, such as those of the metal uranium, give off enough energy to separate or smash other atoms, breaking them into simpler atoms. At the same time that the atoms are broken up, tremendous amounts of energy are released. That is, atoms of other kinds are formed, and some matter is changed to energy. The first use of atomic energy released in this way was in the famous atomic bomb.

Demonstration. What Are Some Properties of Matter?

What to use: Exhaust pump, bell jar, plate, tubing, flask, solid stopper, wire, match, cloth or touch paper.

What to do: Set up the apparatus as shown in the illustration. Wrap the end of the wire around the touch paper and light the paper. Hold it inside the flask until the flask is filled with smoke. Put the stopper fairly firmly in the flask, and place it under the bell jar. Pump the air from the bell jar.

What was observed: Describe what you observed. What happened to the stopper? To the smoke?

What was learned: State two reasons for believing that matter contains energy.

Filmstrip: Water. S.V.E.

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* matter, space, mass, weight, elements, chemical means, destroyed, electrons, protons, molecules.

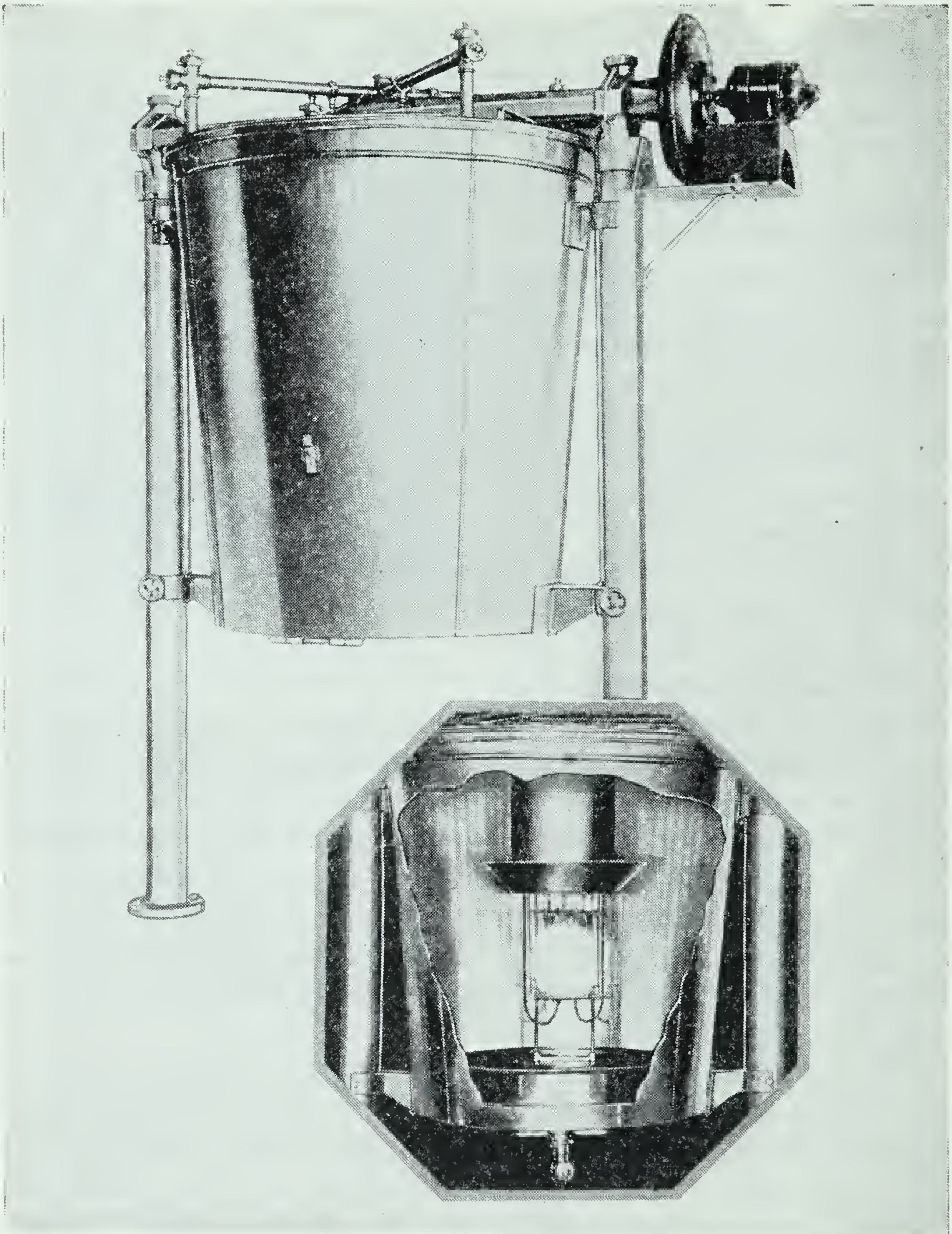
2. What is energy?

Although there is nothing in the world and perhaps nothing in the universe which does not contain energy, energy is the most difficult of all things to define. Because it is universal, energy can be described only in terms of our experience with it and with its effects.

What can energy do? Energy can do work and can produce changes in matter. As you know, when we use the word *work* in science, we mean that something is moved against resistance. Energy is found in every moving object. Flowing water, flying birds, moving clouds, and the oozing lava of the volcano all are alike in possessing energy. All living things depend upon changes in their bodies which result from using a supply of energy. Energy does our work of lifting weights, flying, making goods, and moving matter from one place to another.

What are the common forms of energy? Heat is a form of energy. Can you imagine a world without heat? In such a world not only would the waters of the ocean be frozen, but the materials of the air would lie like snow upon the ice. There would be no clouds in the sky, no wind, no sunshine. The temperature would always be the same, 459 degrees below zero Fahrenheit. This temperature is called absolute zero.

Not only would the larger particles of matter be still. Even the molecules would have stopped their seemingly ceaseless motion. Although we refer to many things as being cold, nothing which we know on earth is really cold. Even dry ice, in a world without other heat, would be hot! As long as the



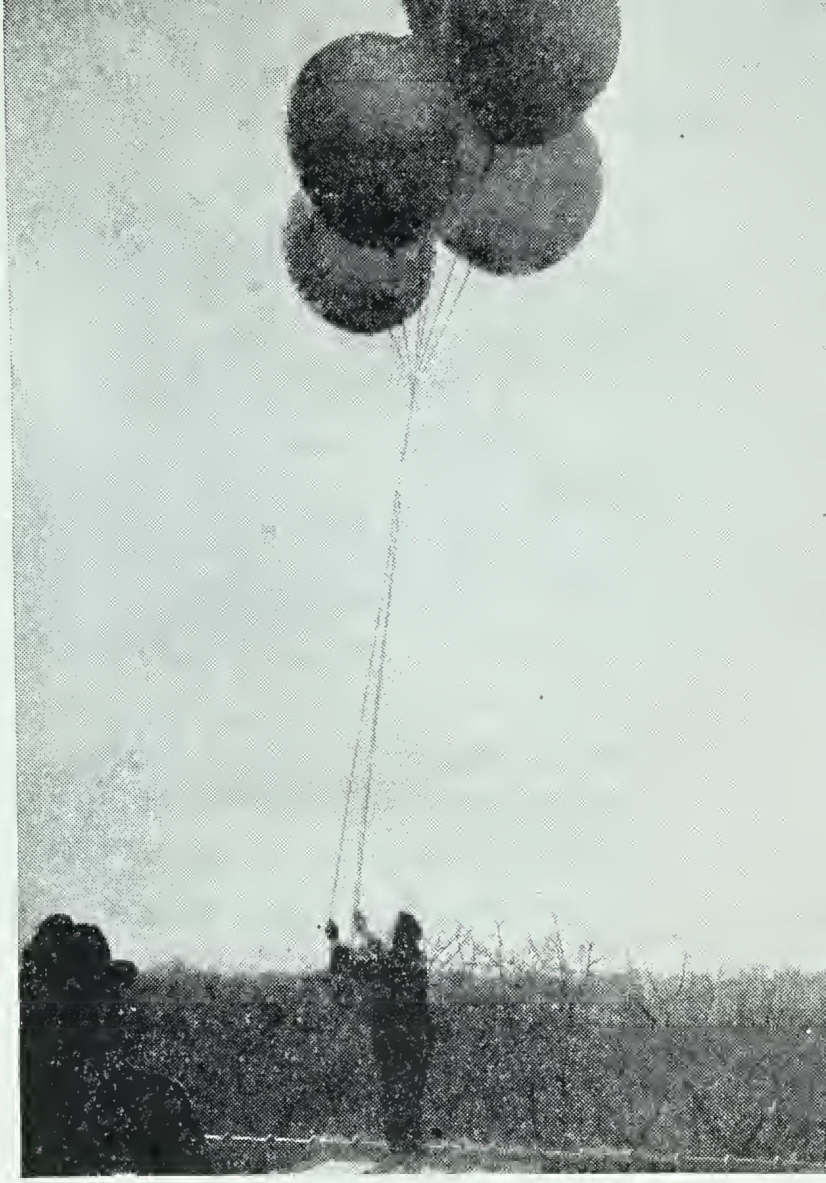
Courtesy Irradiated Evaporated Milk Institute

The outer view of the milk irradiator shows the container and pump. The inner view shows the milk flowing down the sides of the container and the lamp which gives off ultraviolet rays to produce vitamin D in the milk.

molecules vibrate, the object which they make up contains heat.

Another form of energy is mechanical energy. When a baseball is thrown by the pitcher, it contains energy. When the batter strikes it, it takes on more energy to change its direction and rate of motion. Energy is transferred from the bat to the ball in this case. The flying ball eventually loses its speed as its energy is changed to heat by the friction of the air, the ground, or the fielder's glove.

Electrical energy is caused by motion of electrons from one place to another. When these tiny charges of negative electricity are released from their positions in molecules and caused to flow along a wire, we can use their energy to do work or to produce heat.



Courtesy National Bureau of Standards

To measure cosmic radiation, balloons have been sent to a height of 23 miles to carry delicate instruments. Cosmic radiation is most intense at a height of about 12 miles and varies from day to day.

What is radiant energy? Several types of energy are alike in that they are not held in matter but travel through space. This energy that travels through space in waves is called radiant energy. It is difficult to imagine waves in space, just as it would be difficult to picture a wave in water without the water. As you know, waves may be close together or far apart. The distance from one wave to another is called wave length. Waves close together have a short wave length; those far apart have a long wave length.

It has been found that there are many forms of radiant energy. These forms, so arranged that the first has the shortest wave length and the last the longest, are cosmic rays, radium rays, X rays, ultraviolet rays, light, infrared rays, and radio

waves. The shortest of these rays are measured in units smaller than a millionth of an inch, and the longest in units which compare to miles. All these forms of radiant energy together are called electromagnetic radiations.

The shortest waves or rays have the most energy. If you hold in your hand a rope which is tied to a post, the faster you shake the rope, the closer together you can make the waves. Just as is the case with the rope, if radiant waves contain more energy, they are closer together.

Some rays have practical uses. Radium rays are used to treat cancer. X rays are used for photography of the interiors of things through which we cannot see. Ultraviolet rays promote growth and cause sunburn. Light is made up of the forms of radiant energy which we can see. Infrared rays are the warming rays we can feel from a hot stove or radiator. And radio waves bring us news and entertainment from distant places.

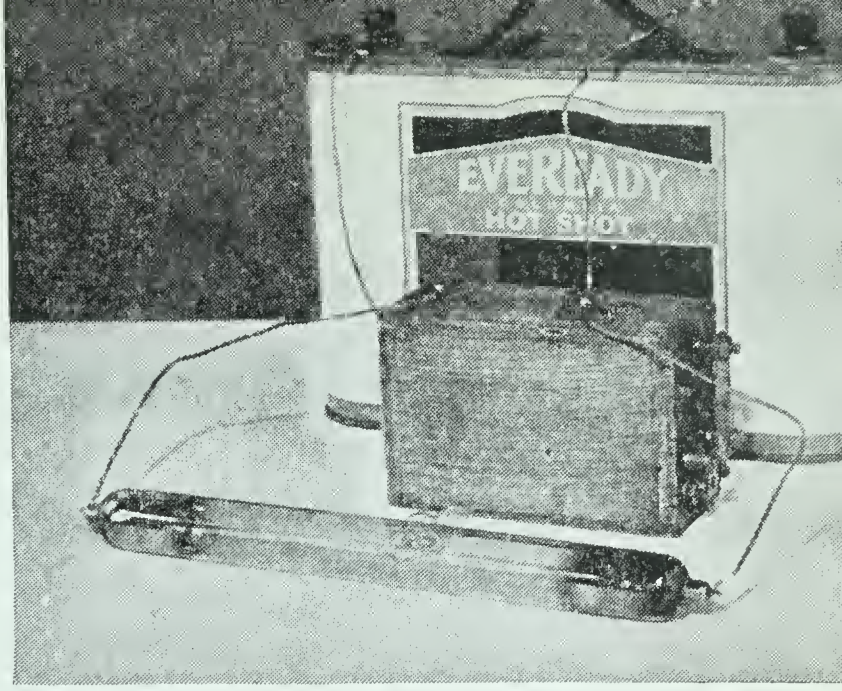
Can energy be destroyed? When you drive into a filling station and buy gas, you are buying a certain amount of energy. The energy is released when the gasoline is burned in the cylinders of the engine. The engine gives off heat in the radiator, in the exhaust pipe, and through the walls of the cylinders. The pistons move up and down, thus moving the rods and gears which apply energy to the wheels. The wheels spin around and move the automobile forward. The tires skid and rub on the ground, changing their mechanical energy to heat. The air flows past the automobile and is warmed slightly as it goes on its way, taking with it some of the energy for which you paid your money.

Attached to the engine is a generator which makes the electric current to run your automobile. It produces chemical changes in the storage battery and makes the spark which fires the gasoline. Electricity operates your car radio, producing sound waves which are a kind of mechanical energy. The lights shine out with the energy from your gasoline.

Every change of energy from one form to another was accompanied by a loss of useful energy. But no energy is destroyed by your automobile. Some of it may be carried from your tires to the road in the form of heat; some may be shooting out through space millions of miles away; some

may be stored up in the chemicals of the battery. But energy cannot be created or destroyed.

What is the value of atomic energy? One of the most interesting problems of science today is to learn to control and to use safely the energy which can be released from the atom itself. We know that such energy is available and that it can be produced in the form of heat, light, and several kinds of radiations. It can be obtained from several kinds of atoms. But to harness it to produce such usable forms as electricity, mechanical energy, and the small amounts of heat needed in our homes and industries is very difficult. Perhaps in the future atomic energy will replace other sources of energy. But at present we must continue to depend upon burning coal for most of our useful energy and upon water power, oil, and gas for the rest of it.



This apparatus shows an old automobile induction coil attached to a neon tube. The induction coil sends an electrical discharge through the neon gas, causing it to glow.

DEMONSTRATION. MAY ONE KIND OF ENERGY PRODUCE ANOTHER?

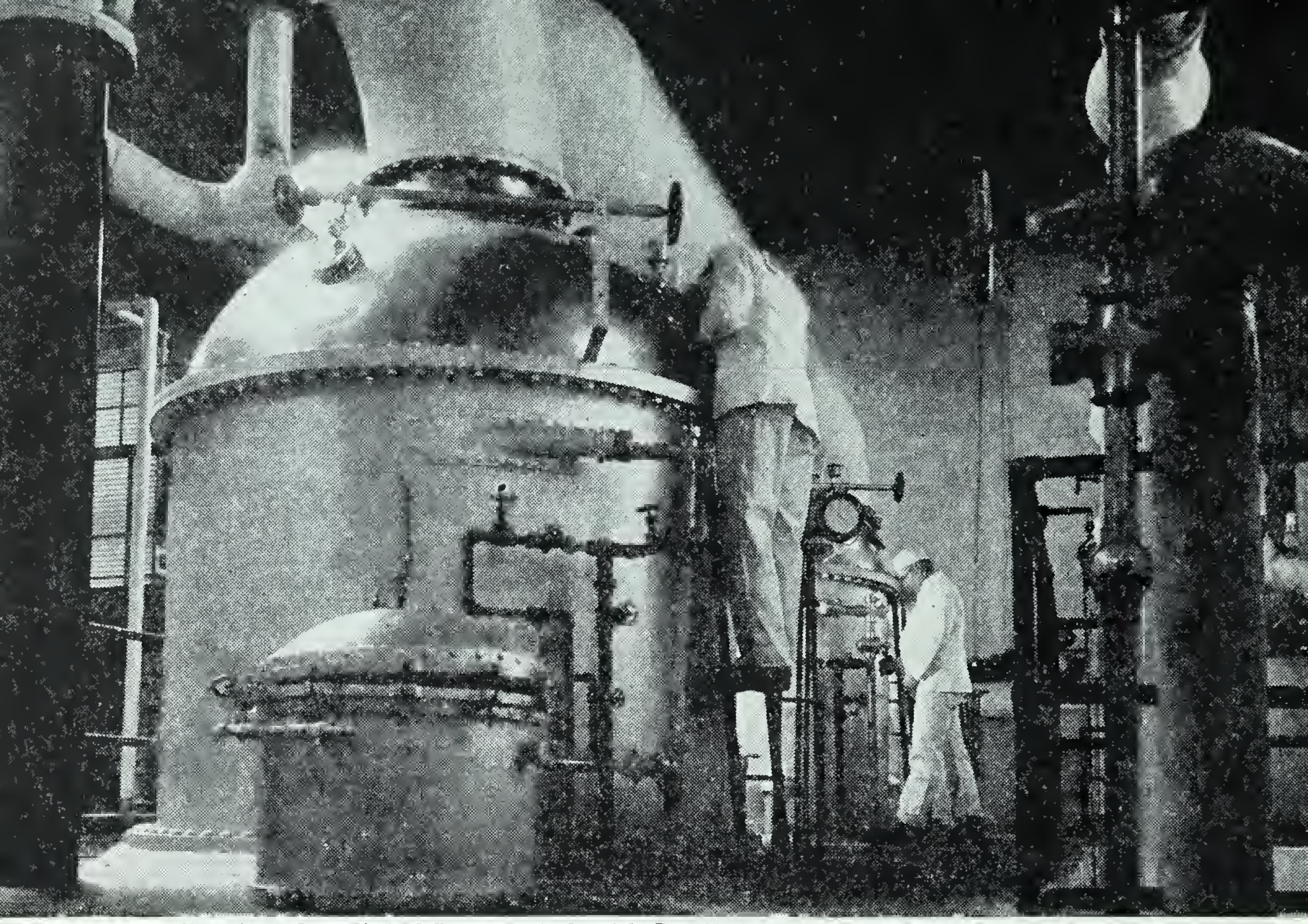
What to use: Dry cells or hot spark battery, induction or automobile spark coil, aurora tube (neon).

What to do: Set up the apparatus as shown in the photograph. Observe the glowing light. Feel the tube to learn if it becomes hot. Electrons from the coil cause the gas in the tube to glow.

What was observed: Was there any difference in brightness of various parts of the tube? Does the coil change the current in any way?

What was learned: How does the neon sign operate? Can one kind of energy be transformed to another? What kind of energy comes from the tube?

Filmstrip: Madame Curie (radium). Metropolitan Life Insurance Co.



Courtesy Irradiated Evaporated Milk Institute

In these huge vacuum pans the air pressure is reduced to make possible evaporation of water from milk without beating it too much. The reduced air pressure lowers the boiling point in making evaporated milk.

Exercise. *Complete the following sentences:* —1— is that which is capable of doing —2— or producing a change in matter. —3— is the energy possessed by molecules in —4—. Molecules constantly move because they are never absolutely —5—. —6— energy travels through space. —7— energy is related to moving objects. Most of our energy comes from the —8—. To obtain controlled energy, we generally burn —9—. The only electromagnetic radiation which we can see is —10—.

Science activity. From a used-car dealer or a wrecked automobile obtain a coil, and perform various experiments with it. Report your results.

3. How do we make use of the forces of nature?

The term "forces of nature" refers to any form or display of energy not directly under the control of man. Some of these—the lightning, the mountain landslides, and the geysers —are of little direct use to us. But others are so vital to our

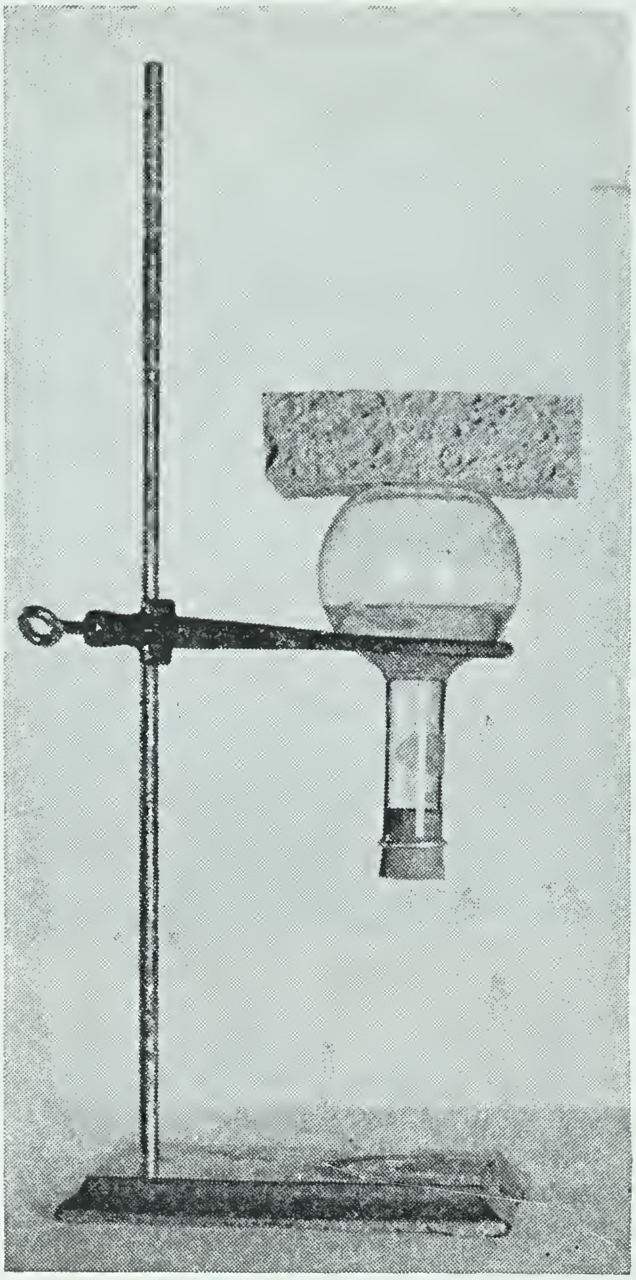
everyday lives that we use them constantly, often without thinking of their value to us.

How does air pressure affect the boiling point? We boil water as a daily task, for we do it every time we boil potatoes, make soup, or prepare tea. We are inclined to think of all boiling water as being equally hot. Yet the boiling point of water depends directly upon the air pressure. At sea level water boils at 212 degrees Fahrenheit. But at considerable elevations, because of the reduced pressure, it boils at a temperature considerably less than this. In fact, water boils so readily on high mountains that there it is almost impossible to cook some foods, such as beans and tough meat, by boiling.

There are certain situations where boiling water at temperatures other than those considered normal is an advantage. When slow-cooking foods are heated above the normal boiling temperature, they become ready to eat much sooner. The pressure cooker is the most practical device for accomplishing this. It consists of a heavy kettle with a tight-fitting cover. The cover is bolted in place after the food is in the kettle. The cover contains a pressure gauge and a safety valve to prevent the cooker from exploding. The safety valve permits steam to escape when the pressure reaches a certain point.

On the other hand, milk is spoiled by boiling, for a scum forms upon it long before it boils. To evaporate milk, it is heated in special cookers called vacuum pans. These vacuum pans actually are large tanks connected to air pumps which keep the pressure low enough that the milk boils before it becomes hot enough to form scum. The milk is heated by steam pipes. When about half the water is removed, the milk is treated in various ways before it is canned. Some milk is radiated with ultraviolet rays to make it richer in vitamin D. Milk is also thoroughly mixed to prevent cream from separating out.

Because water boils more readily when pressure is reduced, it can be made to boil by cooling. If you boil water in a flask until steam drives out all the air and then cork the bottle tightly, the water will boil as it cools. The steam condenses when cooled, which reduces the pressure in the flask. The reduced pressure causes the liquid to boil, and the steam formed condenses in its turn, again causing boiling to take



The cold sponge causes condensation of water vapor in the flask. Why does the water boil?

place. It is actually possible to remove so much heat from a liquid by boiling it in a vacuum that it will freeze from being boiled.

How does gravity affect common liquids? As you know, it is the pull of gravity that gives matter its weight. With liquids, as with everything else, the weight varies with the mass. We use this fact to measure the specific gravity of liquids.

For comparison we say that water has a specific gravity of one. A liquid heavier than water then has a specific gravity of more than one, and a liquid lighter than water has a specific gravity of less than one. A convenient apparatus for comparing the weights of various liquids is shown in the middle illustration of the diagrams on page 118. Two tubes are connected at the top, and the lower ends are dipped into the liquids to be compared. The air is withdrawn from both tubes equally at the top, and air pressure forces each liquid up its tube. The lighter liquid naturally rises higher than the heavier liquid. Thus we can measure the height of the liquid in each tube and obtain a direct comparison of their weights. If we always divide by the height of the tube of water, the result is the specific gravity of the liquid in the other tube.

Gravity also causes liquids to flow downhill. By using gravity and air pressure together, we can make a useful siphon. A tube is arranged so that one end is in a container of liquid and the other end is outside the container, with the

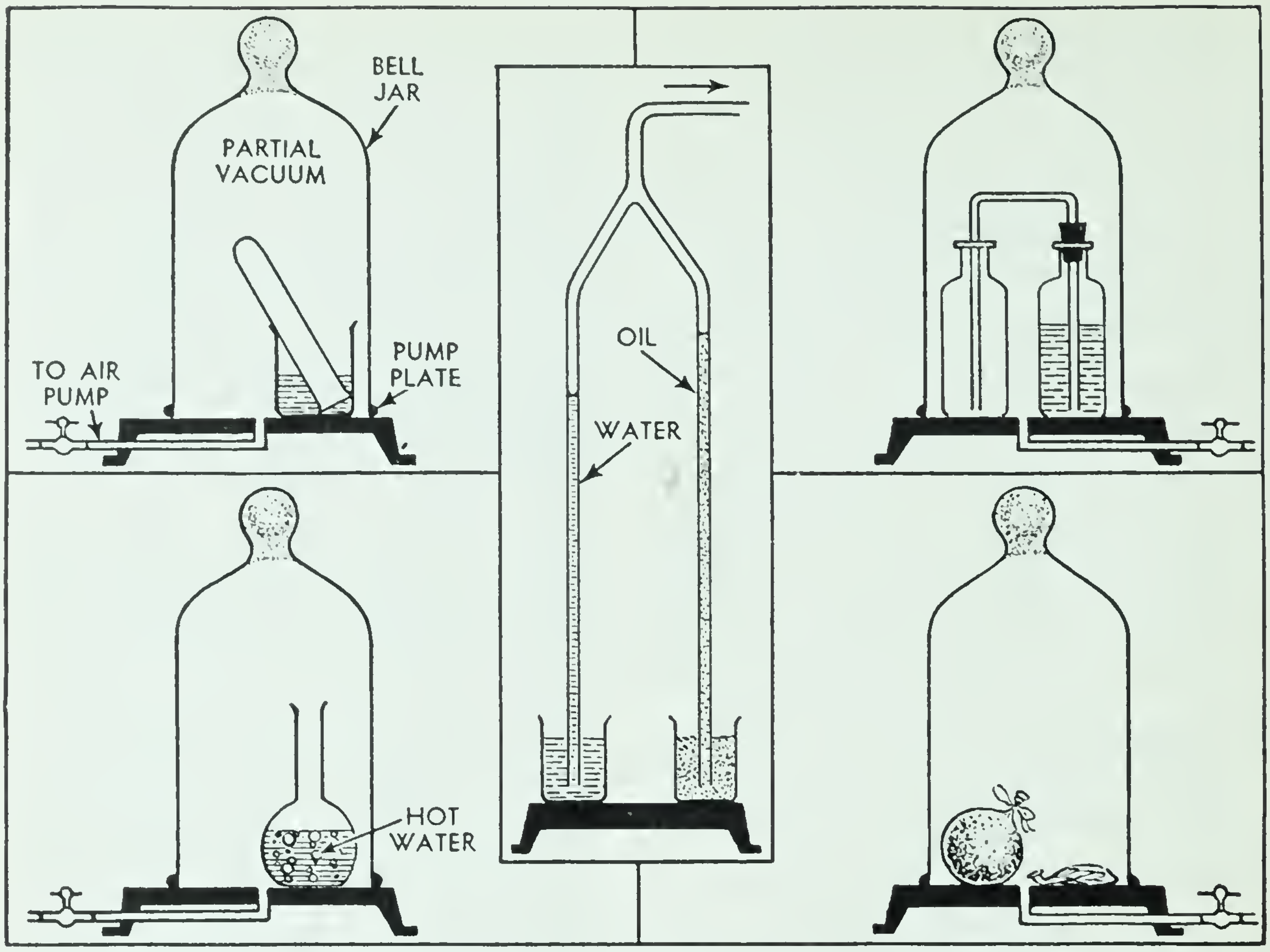
outer end lower than the surface of the liquid. Then if the air is withdrawn from the tube, water flows upward and over the rim of the container. Gravity keeps it flowing as long as no air enters the tube. A siphon is of much practical value for emptying tanks of various sorts. The common toilet bowl has a siphon arrangement. An interesting siphon may be produced in a vacuum as shown in the diagram (*top right*) on page 118. One bottle containing water has a stopper in it; the other is open. You can see how the siphon operates by setting up the apparatus and pumping out the air. Readmit air to see what happens.

The effects of gravity and air pressure acting upon a liquid come to a balance when the pressure of the air has forced up a column of liquid weighing 14.7 pounds and with a cross section of one square inch. As you know, 14.7 pounds per square inch is the pressure of air at sea level. Air can lift a column of water to a height of about 34 feet, a column of mercury to a height of about 2½ feet, and a column of light oil from about 40 to 50 feet, depending upon the specific gravity of the oil. Which is the best liquid to use in a barometer? Why?

When liquids do not mix and when solids and liquids are brought together, specific gravity determines whether a given material will float or sink. For example, a five-cent piece will sink in water and float in mercury, because its specific gravity is more than that of water and less than that of mercury. Oil floats on water, and water floats on mercury.

How do we enjoy forces of nature out of doors? Many of the forces of nature affect our lives so constantly that we take account of them only under unusual conditions. We know that water evaporates into the air all the time, but mention the fact only when we note some unusual effect. For example, if we see "steam" rising from a black-top pavement when the sun is shining, in spite of a below-zero air temperature, it seems worth mentioning. Do you know why you can see "steam" under these conditions?

We are accustomed to seeing water boiling on our kitchen stoves and to seeing standing water out of doors. But when we hear of boiling water shooting up from an opening in the ground, it is unusual enough that we will travel from far off to



Four of these diagrams show how apparatus is arranged for experiments described in the text. The fifth (*bottom right*) shows two balloons—one tied and the other untied—which were almost empty when air pressure was normal. Why does one balloon expand when air is pumped from the bell jar?

see it. A geyser is found only where conditions are just right. Water collects in a deep crack underground and is heated by a layer of hot rocks at the lower part of the crevice. The pressure of the water above prevents the water trapped in the lower portion of the crevice from boiling readily. Finally the trapped water does boil, blowing the water above it through the opening of the geyser. The boiling point is reduced as the pressure is released, and steam continues to form and to force water into the air. When the accumulated hot water is blown off, more water accumulates and is heated in the crevice until the boiling point is again reached.

Demonstration. How Are Some Forces of Nature Used?

What to use: Air pump, bell jar, plate, wax, flasks, bottles, stoppers, tubes, burner, test tube, beaker, oil, water, Y-tube.

What to do: Perform as many of the experiments described in this problem as you can, following the diagrams showing how the apparatus is set up for each experiment. Test the air pump by

inverting a test tube filled with air in a beaker containing enough water to cover the mouth of the tube (*see diagram at top left on page 118*). Place them beneath the bell jar on the plate. Pump out air as long as bubbles escape from the test tube; then readmit air. Unless most of the air is removed, the pump is not in good condition.

What was observed: Write your observations in a few complete, brief sentences.

What was learned: How does air pressure do work? How does air pressure affect the boiling point? How does the weight of oil compare with the weight of water?

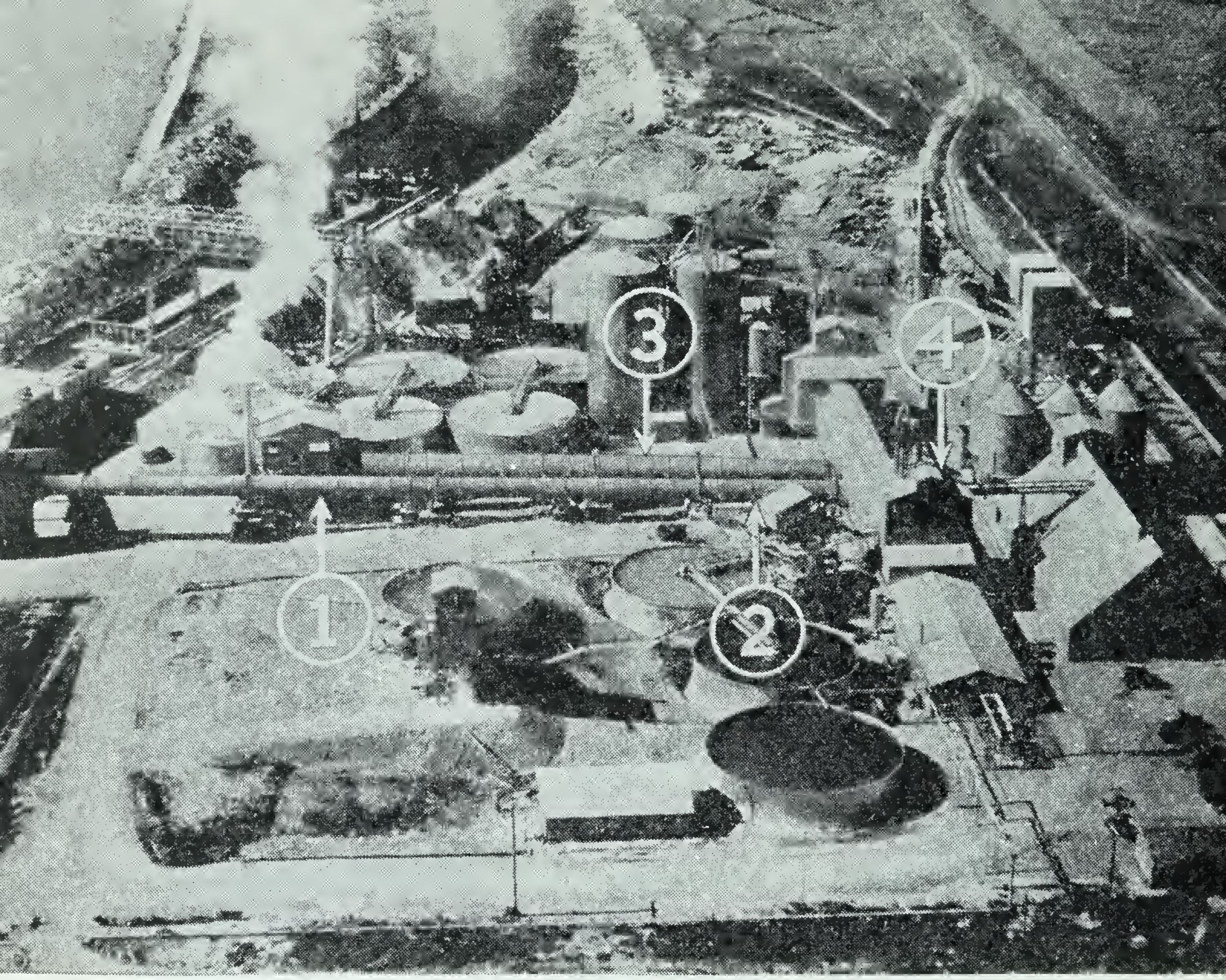
Exercise. *Make a table by ruling your paper into four columns. Head the columns as follows:* AIR PRESSURE, GRAVITY, SUN'S ENERGY, EARTH HEAT. *Consider which of these is most important in causing the natural occurrences discussed in this problem, and write at least 16 changes or natural occurrences into the table. A natural occurrence may belong in two or more columns.*

Science activities. 1) Perform for the class the demonstration of cooling the flask of boiling water (*see picture on page 116*).
2) Make a hydrometer of a weighted stick, and mark it to indicate specific gravity of liquids. Read for information to make your plans. Demonstrate hydrometers before the class.
3) Find out how an iceless refrigerator cools by evaporation, and make a model that actually works.

4. What are the uses of chemical change?

One of the most important ways in which matter can be controlled for our use is by changing it chemically. For example, you have heard the old saying, "You cannot make a silk purse from a sow's ear." Yet a scientist took sows' ears from a packing plant, changed them chemically, made them into rayon, and had them made into a "silk" purse. The rayon purse was later carried by a young woman dressed from head to foot in clothes of the latest style for a formal party. All her clothing was made by chemical means. Her bracelet and vanity case were made of plastics. She appeared before a great scientific society to show man's mastery of materials for practical use, achieved through knowledge of chemistry.

What are chemical changes? You know already that the commonest things with which we deal are chemical com-



Courtesy Westvaco Chlorine Products Corporation

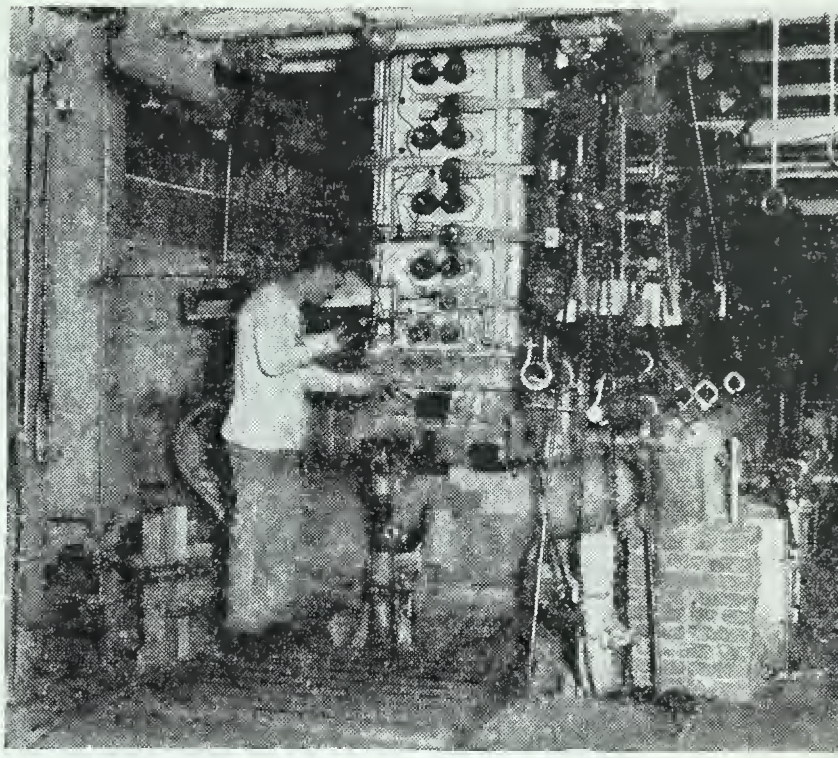
This modern chemical plant produces lime and magnesia—both bases used in industry. Number 1 is the kiln in which lime is separated from limestone. Number 2 is the lime cooler. Number 3 is a magnesia kiln, and 4 is the cooler. The tanks are used for separation and storage.

pounds. That is, most substances are made up of elements combined in certain definite ways.

There are only 92 natural elements on earth, and a few others artificially produced in the laboratory. Here are the names and properties of some of the commoner elements.

Metals	*Symbol*	*Acid Formers*	*Symbol*	*Neutral*	*Symbol*
Iron	Fe	Sulphur	S	Hydrogen	H
Aluminum	Al	Carbon	C	Oxygen	O
Calcium	Ca	Nitrogen	N	Neon	Ne
Sodium	Na	Phosphorus	P	Helium	He
Potassium	K	Iodine	I	Argon	A
Copper	Cu	Chlorine	Cl		
Mercury	Hg	Fluorine	F		

There is no known limit of the number of compounds which can be formed from the elements. Common iron rust is an example of a simple type of compound. It is made up of iron and oxygen. Carbon dioxide is also a simple compound containing two elements. Wood contains carbon, hydrogen, oxygen, and various other substances.



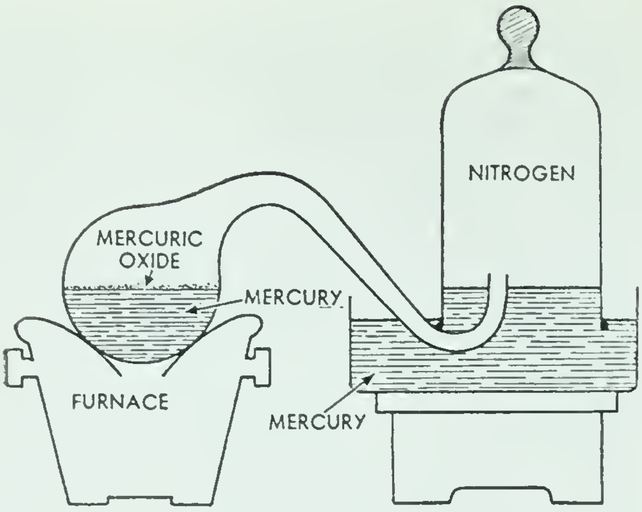
Courtesy Pittsburgh Plate Glass Co.

Chemical changes either absorb or give off energy. Making glass from sand, soda, and other materials requires energy, which is provided by the complex furnace.

Elements may be divided into small parts called atoms. A molecule is the smallest part of a compound. Since compounds are made up of elements, it follows that molecules are made up of atoms. A chemical change is a change which brings about a rearrangement of atoms in molecules, or which produces new combinations of atoms to form molecules.

Why are chemical symbols used? A chemical change always brings about new arrangements of atoms in certain definite proportions. That is, if a pound of carbon combines in an excess of oxygen by burning, the same amount of oxygen is always required to combine with the carbon. If a chemist were to describe the change in words, the description would become long and difficult to follow. Instead of writing out the words, he uses the symbols representing the elements in a chemical equation. The equation which represents the burning of carbon is $C+O_2 \rightarrow CO_2$.

The chemist can get the following information from this chemical equation: One molecule of the element carbon, which contains one atom, combines with one molecule of the element oxygen, which contains two atoms, to form one molecule of the compound carbon dioxide. For each 12 pounds of carbon, 32 pounds of oxygen are required and 44 pounds of carbon dioxide are formed.



This apparatus was used by Lavoisier in performing the first two real chemistry experiments.

The use of symbols expresses exactly what the chemist wants to know. He can apply his knowledge of chemicals to fill in a great deal of information you will not know until you study chemistry.

The use of symbols is more convenient than use of words because it is briefer and more exact.

Who performed the first chemistry experiment? The first chemical change carried on as an experiment was performed by the great French scientist, Antoine Laurent Lavoisier, who lived from 1743 to 1794. His experiment was performed about the time of the Revolutionary War in the United States. He put mercury into a glass container and heated it over a furnace for 12 days. Gradually a red powder formed upon the surface of the mercury. This powder was mercury rust. His apparatus was so arranged that the air was taken from a jar. As air was drawn from the jar by the chemical change, it was replaced by mercury from a dish.

By measurement Lavoisier found that only one-fifth of the air had been used. The remaining gas was not air, because things would not burn in it. He named the gas nitrogen. He then heated the red mercury rust, just as you perhaps have, and collected the oxygen given off. He found that a glowing splinter burst into flame in oxygen.

This famous experiment showed two things: the composition of the air and the nature of burning.

What are three types of chemical change? There are in general three types of chemical change. In the first, elements combine to form compounds. In the second, compounds are decomposed into other compounds or elements. In the third, two or more compounds exchange elements to form more compounds. Every chemical change either results from energy being used to produce the change, or it causes energy to be given off in some form.

The combination of mercury and oxygen is an example of the first type of change. So is rusting of iron, for oxygen and iron combine. Burning of hydrogen in oxygen is also a combination of elements.

When red mercury rust is decomposed, it breaks up into two elements: mercury and oxygen. Most methods of making oxygen are similarly examples of decomposition.

Most chemical reactions are examples of replacement—that is, the exchange of elements to form new compounds. When iron is smelted, the iron oxide gives its oxygen to the carbon of the coke. The iron is freed, and carbon dioxide is formed.

When hydrochloric acid is poured over soda, there is an exchange of elements to form salt, water, and carbon dioxide. The chemical equation for the exchange is $NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$. Although this change may seem complex, it really is one of the simpler types of chemical combinations.

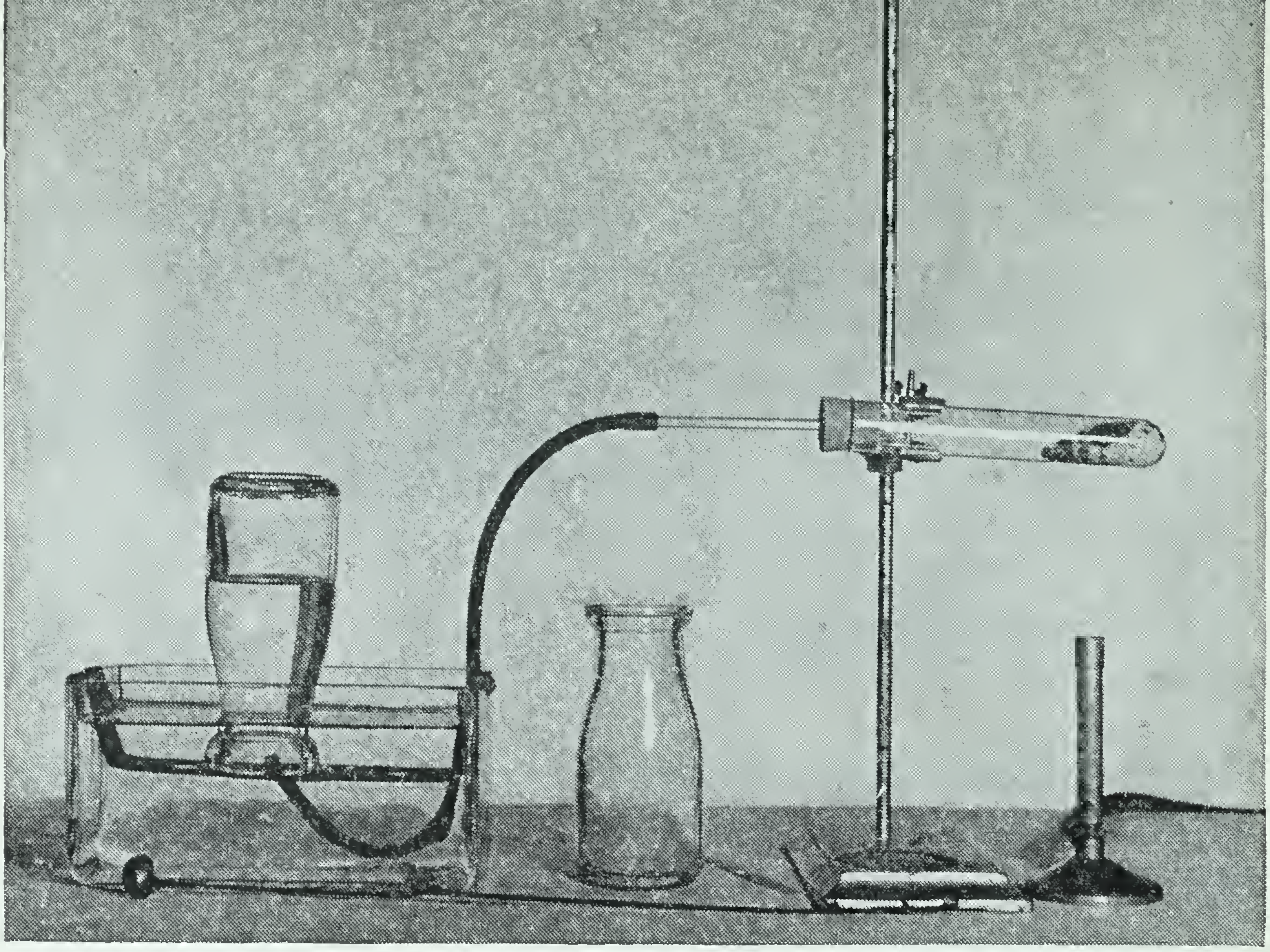
The chemical equation for manufacture of sugar is $6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2$. When the sugar is oxidized, the reaction is reversed. That is, this equation can be read either way, depending on the type of change which takes place.

You are familiar with the test for carbon dioxide. When the gas is bubbled through limewater, a white, cloudy precipitate is formed. Limewater is a solution of calcium hydroxide. The carbon dioxide combines with the lime to form a new chemical compound, calcium carbonate or limestone, which does not dissolve in water. The cloudy appearance indicates the presence of a new chemical compound.

Demonstration. How Does Oxygen Take Part in Chemical Change?

What to use: Test tube, rubber stopper, delivery tube, ring stand, clamp, manganese dioxide, potassium chlorate, burner, gas collecting bottles, glass plates, trough, steel wool, magnesium ribbon, sulphur, deflagrating spoon, splint, litmus paper, forceps.

What to do: Set up the apparatus as shown in the illustration on the next page. Mix a teaspoonful each of potassium chlorate



You should arrange the apparatus in this way to prepare oxygen. Note that one bottle is covered with a piece of glass.

and manganese dioxide in the tube, and heat it. When bubbles are given off freely, collect four bottles of the gas.

Test the first bottle of gas with a glowing splint.

For a control (comparison) burn a small piece of magnesium ribbon in air. Hold the metal with forceps. Burn a second strip in oxygen.

Burn sulphur in the deflagrating spoon in the third bottle. Put a piece of wet litmus paper in the mouth of the bottle.

Wrap steel wool loosely around the handle of the spoon, heat it in the flame, and thrust it into the fourth bottle of oxygen. If there is water in the bottom of the bottle, danger of breakage is lessened.

What was observed: Make notes on what was observed.

What was learned: Does a chemical change produce a new substance? Give at least six examples from this demonstration to illustrate your answer.

Filmstrip: Oxygen and hydrogen. S.V.E.

Exercise. *Complete the following sentences:* The smallest portion of elementary matter is the —1—. When atoms combine, they form —2—. A —3— produces new combinations or arrangements of —4— within molecules. Elements combine to form —5—. When potassium chlorate is heated it produces —6— and

a white salt. Water is a chemical compound of —7— and —8—. The first chemistry experiment was performed by —9—.

Science activity. List as many chemical changes as you can find which take place in your kitchen at home.

5. What things are sour, bitter, or salty?

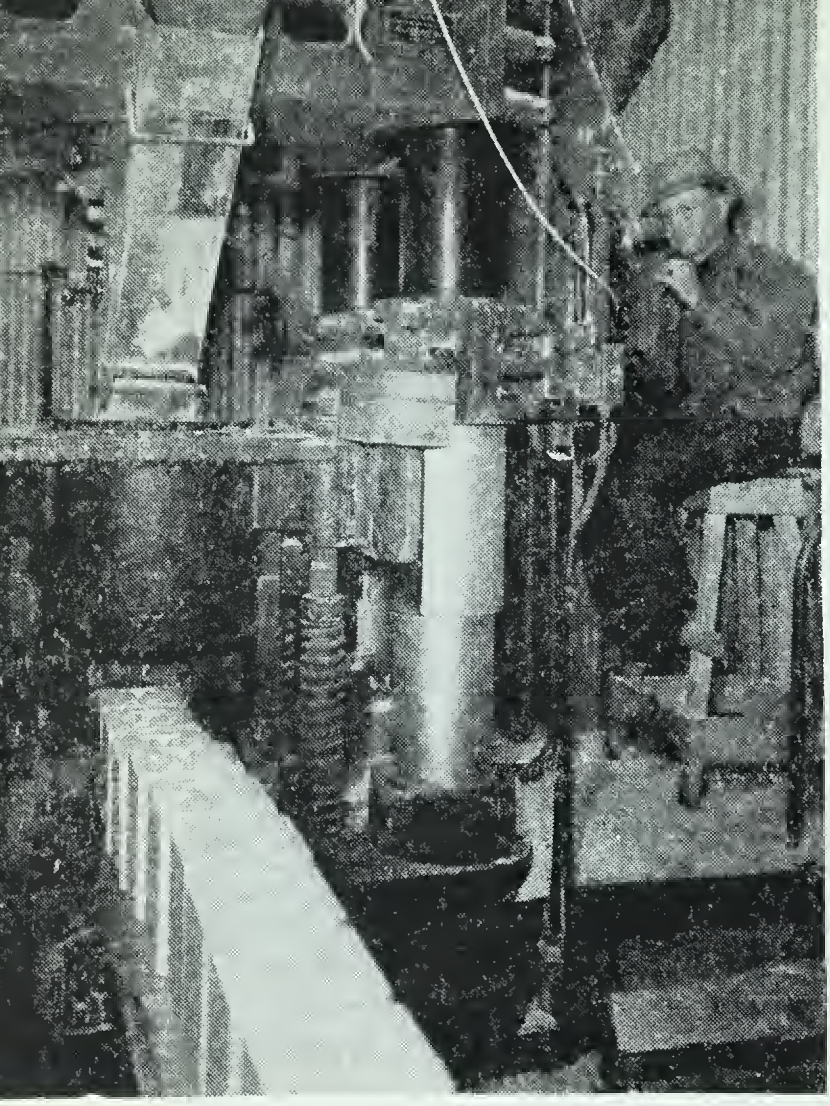
Our four senses of taste—sweet, salty, bitter, and sour—are fairly reliable indicators of the nature of many of the common chemicals. In fact early experimenters regularly used taste as a means of identifying certain chemicals. So many chemicals are sweet, however, that sweetness is not of much value in identifying them.

What are sour substances? The scientific name for a sour substance is *acid.* The word "acid," which in Latin meant *sharp* or *sour,* was applied to vinegar. There are acids in almost all fruits. The acid in apples, lemons, peaches, and grapes can be detected by taste. However, it is not safe to taste the acids in the laboratory, for many are so strong that they may cause serious burns. Some acids are also deadly poisons.

Commercially, the most important acid is sulphuric acid. It is used in automobile batteries and in the manufacture of a great many common chemicals. Sulphuric acid takes water from other substances and burns holes in cloth and wood by changing them to carbon. In weak solutions sulphuric acid destroys cloth by oxidizing it.

The commonest acid used in the laboratory is hydrochloric acid. It is chemically a strong acid, and attacks metals rapidly.

All acids have certain characteristics that make them different from other chemicals. They taste sour, and turn litmus paper red. Litmus paper is made by soaking a vegetable dye into soft paper. A most important chemical action of acids is their ability to attack metals. If you pour a strong acid into an iron or aluminum pan, it will eat holes in the pan by combining chemically with the metal. Hydrochloric acid is said to be a strong acid because it reacts with metals with considerable speed. Vinegar is a weak acid because it attacks metals very slowly.



Courtesy The Hydraulic Press Mfg. Co.

Table salt comes from the hydraulic press in rocklike blocks. These blocks are used to supply farm animals with the salt they need.

What are bitter substances? There are fewer common bitter substances than there are sour substances. The bitter substances found most commonly among chemicals are called *bases*. A base is a substance formed when a metal combines chemically with water.

A base is almost the exact opposite of an acid in its action. Bases turn litmus paper blue and act with acids to form other chemicals.

A few common bases are known to most of us. Lye is used to cut grease in drains and for making soap. Another base used in the home for cutting grease is ammonia. Water-slaked lime is a base used for a great variety of purposes—for making plaster and cement, for tanning hides of animals, for fertilizing and neutralizing sour soils, and for making whitewash. Slaked lime is made by pouring water on quicklime or exposing it to the moist air.

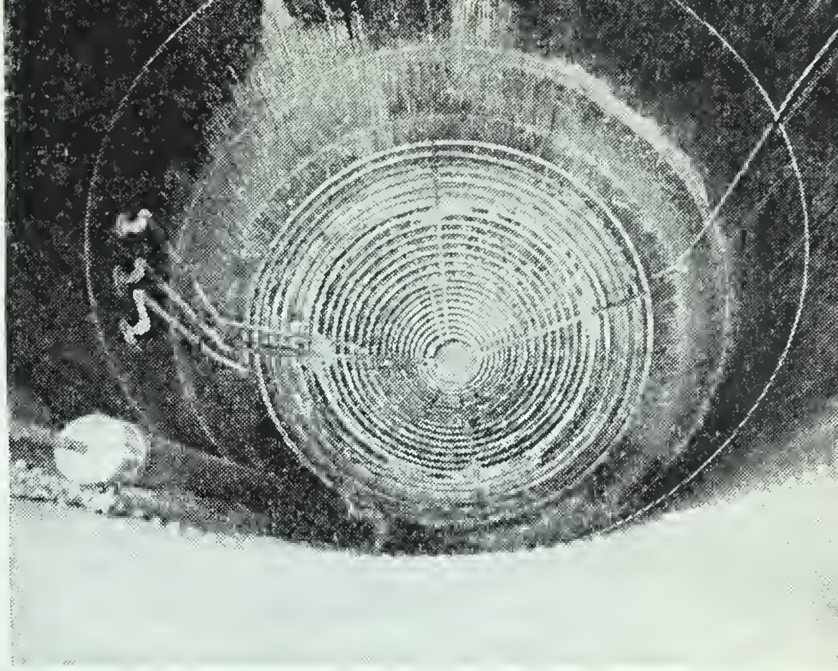
What substances taste salty? Because we put only one kind of salt—sodium chloride—on our food, we may forget that there are thousands of other salts. Baking soda is a salt. Washing soda is a salt. Baking powder contains two salts. Soap is a kind of salt. Dry cells contain another salt—ammonium chloride. One of the first salts discovered is copper sulphate or blue vitriol which is used in spray to kill plant fungi.

A salt is formed when a base or a metal combines chemically with an acid. To illustrate the process of forming salts, let us follow a series of chemical changes which produce common table salt. By using forceps, a small piece of sodium

metal is dropped into water. The sodium combines with water vigorously, skimming about on the surface. Bubbles of hydrogen are given off. The rapid action generates heat which melts the sodium. Sometimes the hydrogen gas explodes, throwing melted sodium into the air. The experiment is dangerous unless performed as directed at the end of this problem.

When the sodium finally disappears in the water, the resulting solution turns litmus paper blue. The water contains sodium hydroxide, a base, the common name of which is lye.

If hydrochloric acid is dropped from a dropper into the lye solution and frequently tested with litmus paper, a point is reached at which the litmus turns neither red nor blue. The chemicals are made *neutral*—that is, neither acid or base. The neutral solution contains ordinary table salt, or sodium chloride. If the water is evaporated, the salt may be collected and identified by tasting it.



Courtesy Procter and Gamble

The soap kettle, heated by coils of steam-filled pipe, is three stories high. You see the top view above. The boiling soap below erupts like a small volcano.

A salt is formed by the reaction of a metal or base with an acid.

Are all salts neutral? We may test hundreds of salts with litmus paper and find that many of them are not neutral, but instead can turn litmus either red or blue. Baking soda turns litmus blue. It is an alkaline salt.

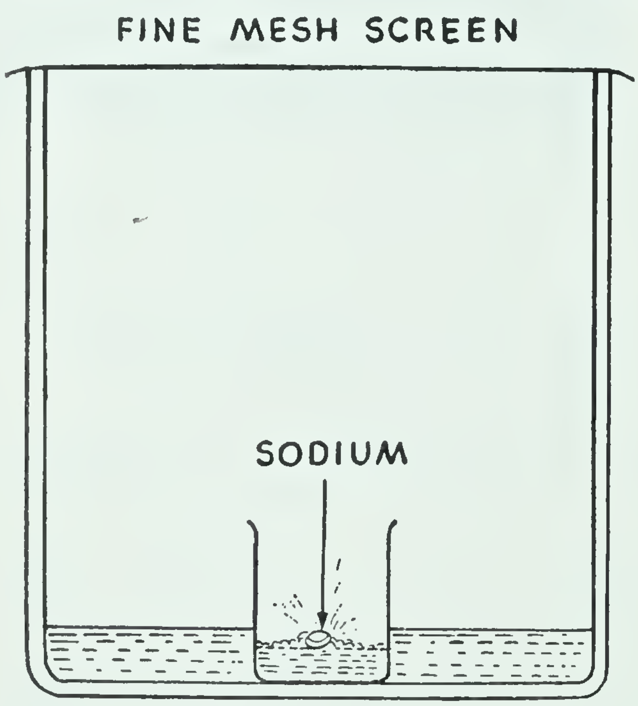
The word alkali comes from an Arabic word which means

wood ashes. The first alkalies were made from ashes. The ashes were put in a V-shaped trough, and water was poured over them. As the water trickled through the ashes, it dissolved out the alkali and was permitted to run out into a container. The water was then evaporated in order to get the alkali or lye.

Many pioneers used soap made from alkali from wood ashes. The alkali was put into a huge kettle with fats and greases, collected from butter and meat, and boiled from one to three days. The resulting soap was often strong, and unattractive in odor and appearance. It was very effective in removing grease, however, because it often contained free alkaline chemicals.

Today lye is manufactured from the salt, or sodium chloride, and is much purer than the lye made from ashes. Much of the improvement of our soaps results from the improved purity of the lye which is used in their manufacture.

Some of the commoner salts are acid—that is, they turn litmus red. A common chemical reaction in cooking uses two salts: one alkaline and one acid. If you were to ask the grocer for such a combination you would say "baking powder." Soda is the alkaline salt. One of the acid salts sometimes used in baking powder is cream of tartar; another is calcium acid phosphate. When the baking powder is wet, the chemicals react to form a fairly harmless salt which is left in the food. The soda gives off carbon dioxide which makes the bread or cake rise.



Use of this apparatus permits combining sodium with water safely. If the hydrogen given off by the reaction explodes, the melted sodium is caught by the screen.

Many cooks prefer to use sour milk and soda instead of baking powder. When milk is attacked by certain kinds of bacteria, the sugars it contains change to acid. The acid when mixed in proper amounts with soda will make bread

rise just as well as baking powder does. In addition, the milk contains valuable food materials which are not found in baking powder.

In the case of the chemical reactions between soda and an acid salt or soda and sour milk, the salt finally produced is neutral.

DEMONSTRATION. WHAT ARE ACIDS, BASES, AND SALTS?

What to use: Sodium, battery jar, 100 cc beaker, litmus paper, hydrochloric acid, fine wire gauze or wet towel, forceps, knife.

What to do: Set the apparatus up as shown in the diagram on the opposite page. Cut a piece of sodium the size of a pea, *handling it with forceps.* Clean it by blotting and scraping. Drop the sodium into the beaker; quickly cover the jar with gauze or wet towel, and *stand back.*

When the action stops, remove the beaker and test the liquid in it with litmus paper. Test hydrochloric acid with litmus paper. Pour dilute hydrochloric acid, drop by drop, into the solution in the beaker until the resulting solution will not change the color of litmus paper. When the solution is completely neutral, taste it. If you have time, evaporate the water until only the resulting salt is left behind.

What was observed: Describe the action and the result of the various tests.

What was learned: How is a base formed? How are chemicals neutralized? What is a salt?

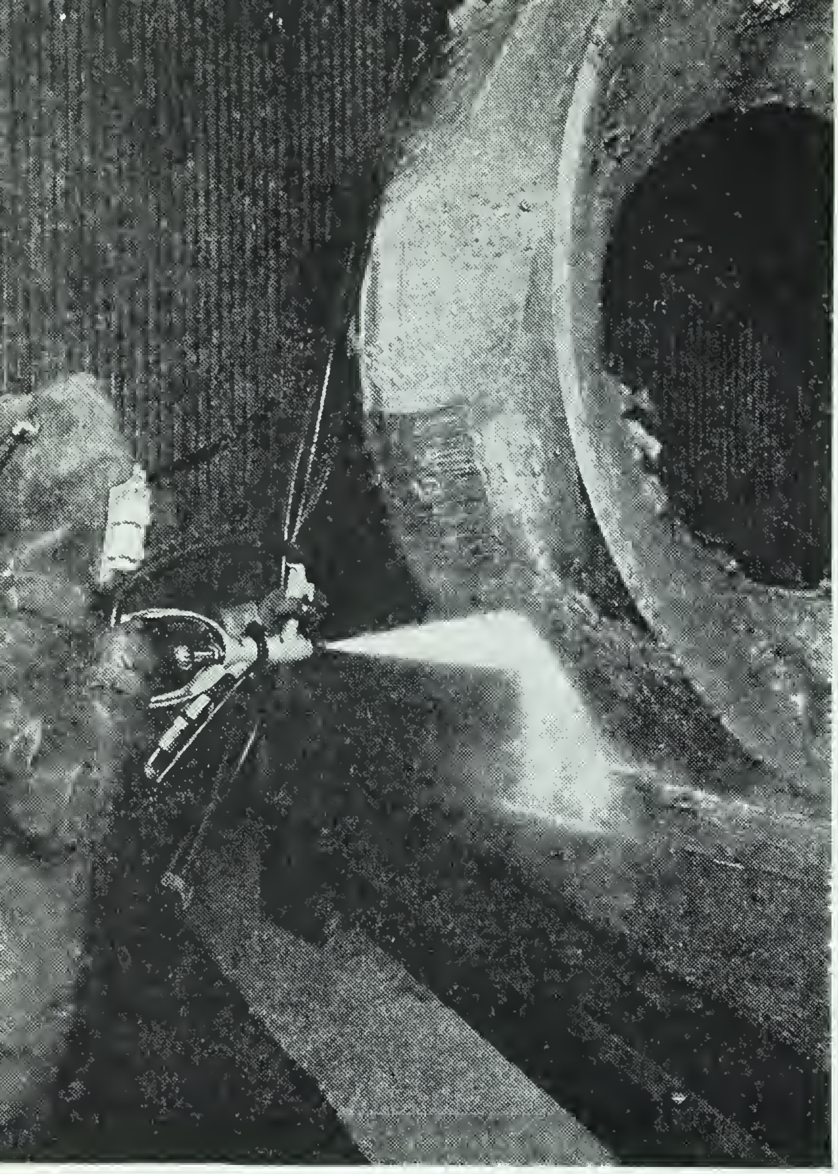
Exercise. *Make a table by ruling your paper into four columns. Head the columns as follows:* CHARACTERISTICS, ACIDS, BASES, SALTS. *Under* CHARACTERISTICS *write these words:* Taste, Effect on litmus, Reacts with, Examples. *Complete the table with information from the text.*

Science activities. 1) Devise ways of testing the amount of gas given off by baking powder when it is wet. You can do this with equipment found at home.

2) Make biscuits at home, using vinegar and soda instead of baking powder.

6. How can we change the form of matter?

Although many of the important changes in matter are chemical, many others are not. When a change does not pro-



Courtesy Hydro-Blast Corporation

Sand is driven in a stream of water to polish the huge piece of cast iron. This is a typical physical change. Why?

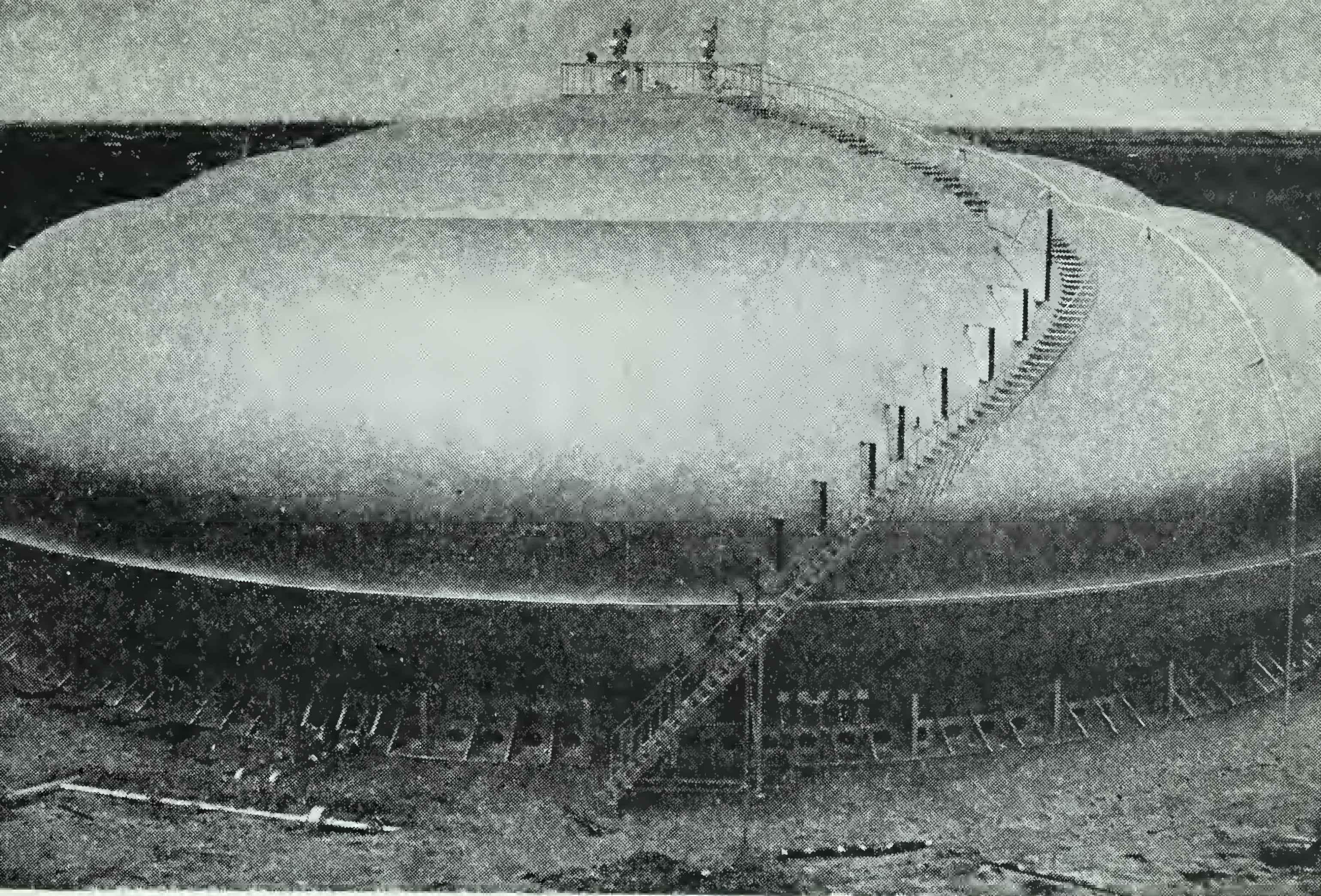
duce a new substance by rearrangement of atoms in a molecule or by new combinations of atoms to form molecules, the change is physical.

How are physical changes related to changes in energy? Every change that takes place anywhere in the universe results either from energy being supplied from some source or in energy being given off. Physical changes depend upon energy changes just as much as do chemical changes.

The commonest of all physical changes dependent directly upon heat energy are the freezing and thawing of water and the evaporation and condensation of water. When we melt a piece of ice, a definite amount of heat is required for each pound of ice. When water freezes, all the heat taken in when ice melts is given off. A freezing pond actually warms the surrounding air because it gives off the heat stored in the water.

When heat is applied to water, the water evaporates or boils, depending upon how rapidly the heat is applied. The vapor formed contains more energy than does the original water. When vapor condenses, the heat is given off. A steam radiator is kept warm by the heat given off by condensing steam. When a cloud forms from water vapor in the air, the air is warmed.

What are the three states of matter? The three states of matter are solid, liquid, and gas. A solid contains less energy than a liquid or gas made up of the same chemical. Solids have a definite shape. It is believed that the molecules of a solid do not move far from their fixed position. That they



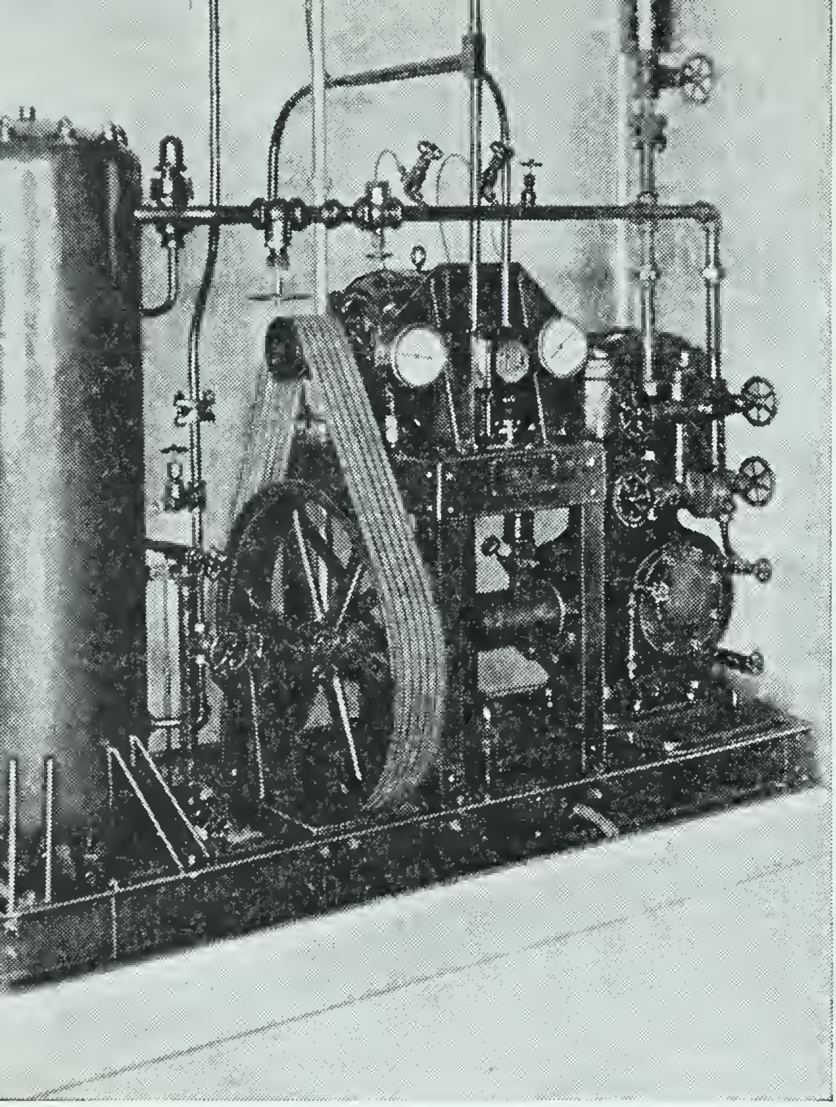
Courtesy Chicago Bridge and Iron Company

Gas molecules contain so much energy that gases must be confined in closed containers. This container, called a spheroid, is used for storage for natural gas.

move somewhat has been proved by an experiment in which polished pieces of lead and gold were fitted tightly together. After four years it was found that molecules of gold had traveled a fifth of an inch into the lead, and molecules of lead had traveled into the gold. In general, however, molecules of solids are quite definitely fixed in their places.

When most solids are heated sufficiently, they change to liquids. But some solids—wood, for example—will not melt. When wood is heated, a chemical change takes place. But all the metals and most other chemicals will melt if heated sufficiently. Some chemicals, such as water and mercury, are liquids at ordinary temperatures.

The molecules of a liquid are free to move and slide around one another. When a liquid is poured, it forms a round stream because the molecules pull upon each other. When a liquid forms a drop, the drop is round. Liquids in containers take the shape of the container, whatever it may be and, because



Courtesy The Frick Company

A common physical change is manufacturing ice. This machine for ice-making removes energy from water and sets it free. The water changes to ice.

of gravity, flow until they reach the lowest point of the container.

Because of their tremendous energy, gases are speeders in the world of matter. A molecule of hydrogen moves about a mile a second at ordinary temperatures. Heavier molecules move more slowly in proportion to their weight. Because of the gravity of the earth, few gas molecules fly fast enough to shoot out into space and become lost. The moon, however, has no air because its smaller gravitational pull will not hold gas molecules.

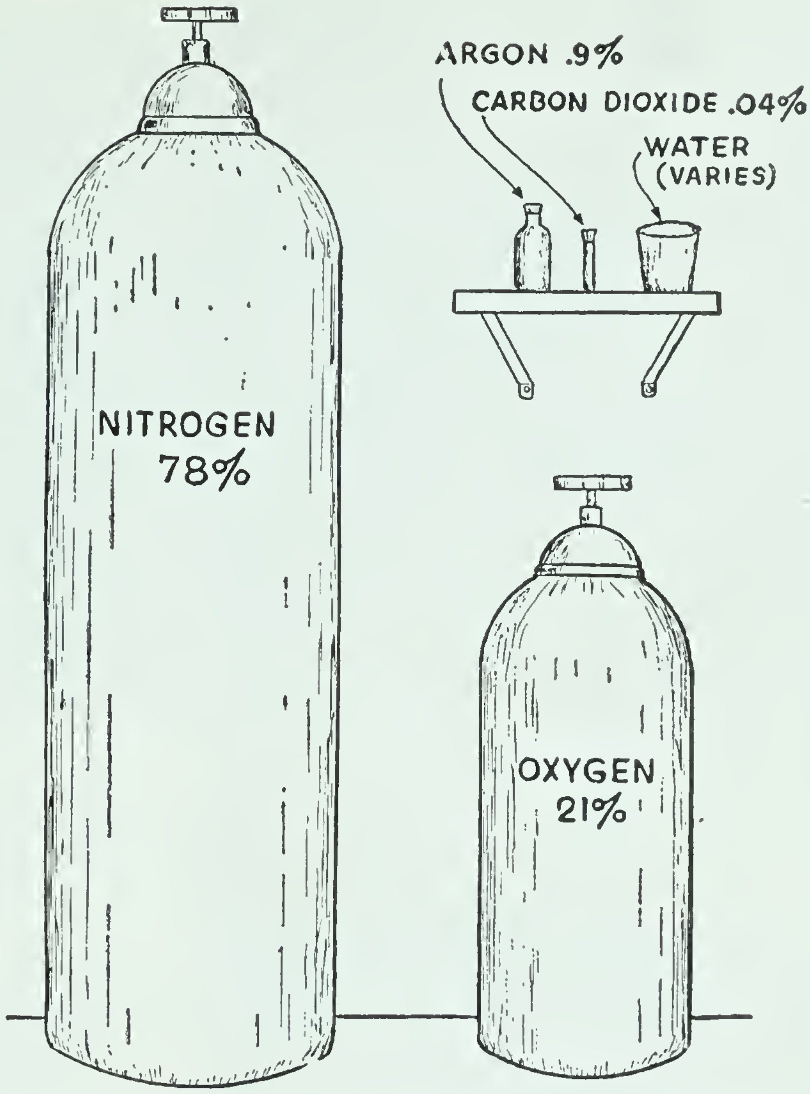
When gas is put into a balloon, the molecules immediately bombard the balloon and cause it to increase in size. A gas molecule is perfectly elastic, and does not change its shape or lose energy when it strikes a surface, if the theory of gases is correct. When gases lose energy, they are cooled and finally change back to liquids.

What causes expansion and contraction? When a solid is heated, but not enough to change it to a liquid, it still undergoes a physical change. It increases in size because, as the molecules gain more energy, they tend to push one another away a small distance. Railroad rails are often laid with spaces at their ends to allow for expansion of the metal. Pavement is similarly provided with spaces between the blocks.

One of the most useful applications of expansion is in thermometers. The metal expands in the tube in proportion to the temperature.

Most substances expand uniformly when they are heated,

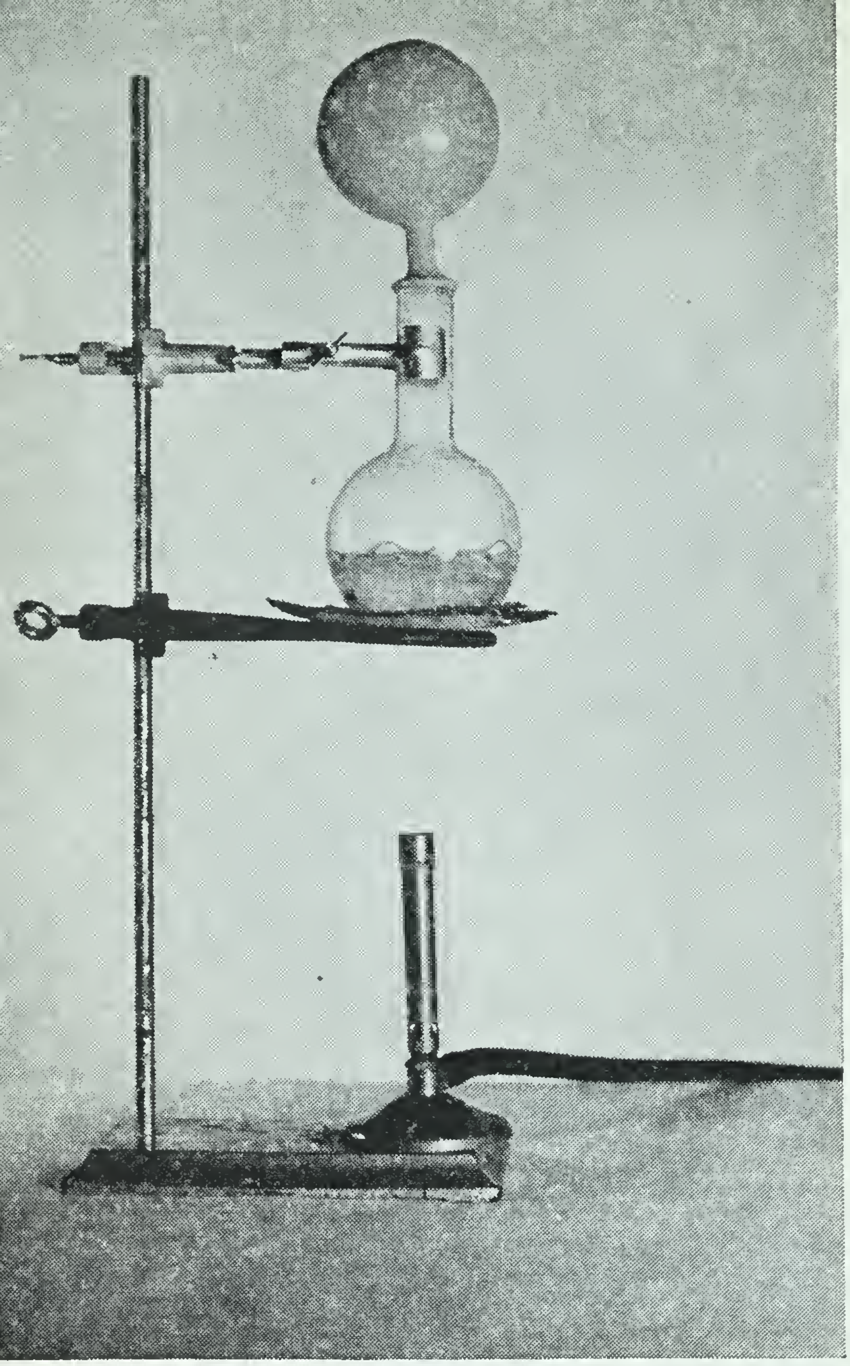
and contract uniformly when they are cooled. Water offers an interesting and important exception to this rule. Water contracts until it is cooled to 39 degrees Fahrenheit, and then begins to expand as it approaches freezing temperatures. Thus in summer the top of a lake is warmer than the bottom, but in winter the bottom is warmer than the top, unless the lake is frozen solid. There are not more than two or three times in a year when the temperature of the lake is uniform from top to bottom. These differences in temperature cause yearly changes in the position of water in the lake, being in effect equal to stirring the water.



Air is a mixture of gases and can be separated mechanically into its parts.

What is the difference between a physical mixture and a chemical compound? Many common things around us are physical mixtures. The air is the commonest and most necessary physical mixture. It is a physical mixture because its gases can be separated out by such physical means as cooling. The different gases change to liquids at different temperatures. The gases of the air may also be separated by collecting them as they boil from liquid air.

Cake is a physical mixture of the sugar, flour, baking powder, fat, milk, eggs, and salt. No other important chemical change takes place in any of the material in the cake except in the baking powder. As you can see, physical mixtures are made up of the same materials after mixing as



The balloon is blown up by the pressure of the steam. What happens as the flask cools?

before. A chemical compound, on the other hand, results when materials are mixed and undergo a change in the make-up of the molecules.

To illustrate a chemical change similar in appearance to many physical changes, we may consider the making of carborundum. To make this grinding material, carbon, or coke, and sand are mixed together and put into a furnace. The two materials are heated at a very high temperature for several hours, and both the sand and the carbon disappear, to be replaced by very hard, sharp crystals of carborundum. No amount of physical effort will separate the carborundum into sand and carbon.

Demonstration. What Are Physical Changes?

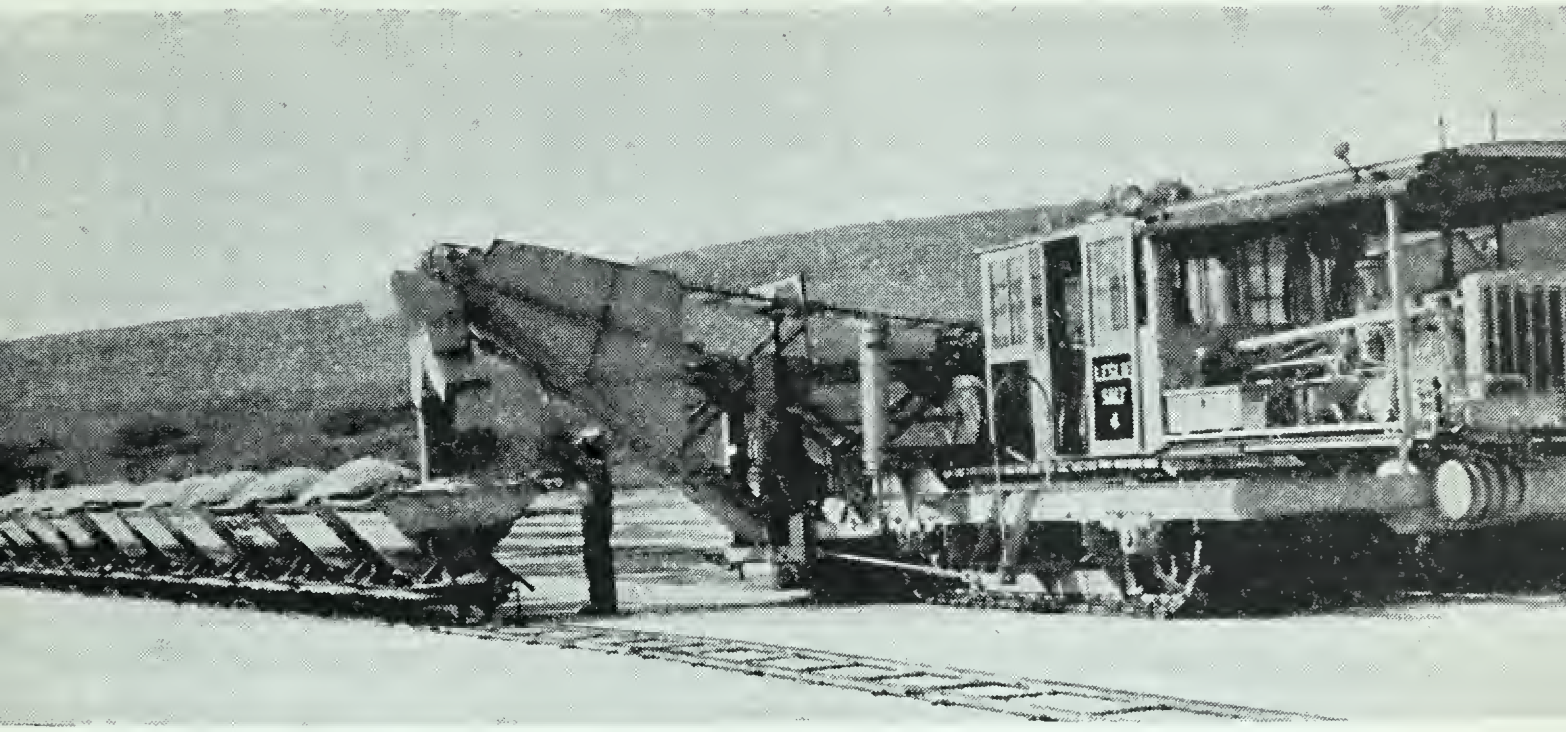
What to use: Flask, burner, ring stand, ring, clamp, gauze, ball and ring, balloon.

What to do: Set up the apparatus as shown in the picture. Before slipping the balloon over the neck of the flask, permit the water to boil for a moment. Heat the flask gently. Permit the flask to cool. Again heat it. As the water boils, remove the burner and, with a cloth to protect the hand, squeeze the balloon. Can you affect the rate of boiling?

Slip the ball through the ring. Heat the ball. Try to slip it through the ring. Heat the ring. Again try slipping the ball through. Cool the ring and repeat. Cool the ball and repeat.

What was observed: Describe the results from each experiment.

What was learned: What force causes the balloon to expand?



Courtesy Leslie Salt Company

When the liquid solvent is evaporated, the solid solute is left behind. Common salt is prepared by evaporating sea water. The salt is being loaded into hopper cars.

To go into the flask? How does pressure affect boiling? Why do materials expand and contract?

Exercise. *Complete the following sentences:* When the molecules of a substance are the same after a change as before, the change is —1—. Matter exists in three states, —2—, —3— and —4—. The state of matter depends upon the amount of —5— present in the matter. —6— have definite form and volume, —7— have neither definite form nor volume, while —8— have definite volume but not definite form. Expansion is a —9— change. Water is densest at —10— degrees Fahrenheit. Air is a physical —11—, and water is a chemical —12—.

7. What are some common liquids?

Although many types of liquids are formed by melting solids or by cooling gases, not nearly all liquids are formed in this way. There are several other types of liquids which we use in the home, in school, and in industry. The commonest four are solutions, chemical elements and compounds, suspensions, and emulsions.

What are the liquid elements and compounds? Although most of the 92 natural elements can be made into liquids if

cooled or heated enough, only a few are liquid at ordinary temperatures. Mercury is one of them.

The commonest of all liquids, water, is a chemical compound. A chemical compound is made up of definite proportions of elements combined with each other. Pure alcohol is a chemical compound of carbon, hydrogen, and oxygen. Carbon tetrachloride, a cleaning fluid, is a compound of carbon and chlorine.

What are some common solutions? A solution is made of some substance dissolved in a liquid called a solvent. The dissolved material spreads evenly through the solvent as long as more will dissolve. Every drop of a solution contains exactly as much dissolved material as any other drop. The molecules of the dissolved material move freely through the solution.

Solutions generally can be made to dissolve more of a solid by heating the solvent, although this is not always the case. In the case of a dissolved gas, heating the solution drives off the gas.

A solid will not dissolve in a liquid which will not wet it. Boric acid powder is soluble in water, but water wets it so slowly that making solutions is difficult. A special chemical is sometimes used to increase the speed of wetting materials. A few drops of the chemical in a pan of water makes the water much wetter—so wet, in fact, that a duck placed in the water sinks up to his neck, and his feathers hang soaked and limp.

Tea is a solution in which both the flavoring and coloring matter of the tea leaves, as well as sugar, is dissolved. Ink is a solution of a solid in a liquid. There are different kinds of inks. The washable school ink is a coal-tar dye dissolved in water. Some ink contains an iron salt and a vegetable dye. Bluing is another solution. Many materials in the medicine cabinet are solutions.

Some solutions contain alcohol as a solvent. Tincture of iodine is the element iodine dissolved in alcohol. Shellac dissolves readily in alcohol. Most flavoring extracts are largely alcohol in which an oil or fat from a plant has been dissolved. Vanilla extract comes from a kind of bean or is manufactured from coal tar.

Carbon tetrachloride and gasoline are solvents of considerable commercial importance. They are used in dissolving grease and oil and in dry cleaning.

Many solutions contain two or more liquids. If a quart of water is poured into a container first, and a quart of alcohol carefully poured on top, a two-quart container will be filled. When the liquids are stirred together, they seem to shrink as the molecules of one liquid fill the spaces between the molecules of the other.

Several gases dissolve readily in water. Soda pop contains dissolved carbon dioxide. Although carbon dioxide reacts chemically with water to form a weak acid, known as carbonic acid, most of the gas is in solution and not in chemical combination with the water. As the pop is warmed, bubbles escape. Pop also contains in solution sugar, coloring matter, and flavoring.

Ammonia is a gas which dissolves in water. It is a common household cleanser, as well as a science laboratory chemical. Hydrochloric acid is a solution of the gas hydrogen chloride.

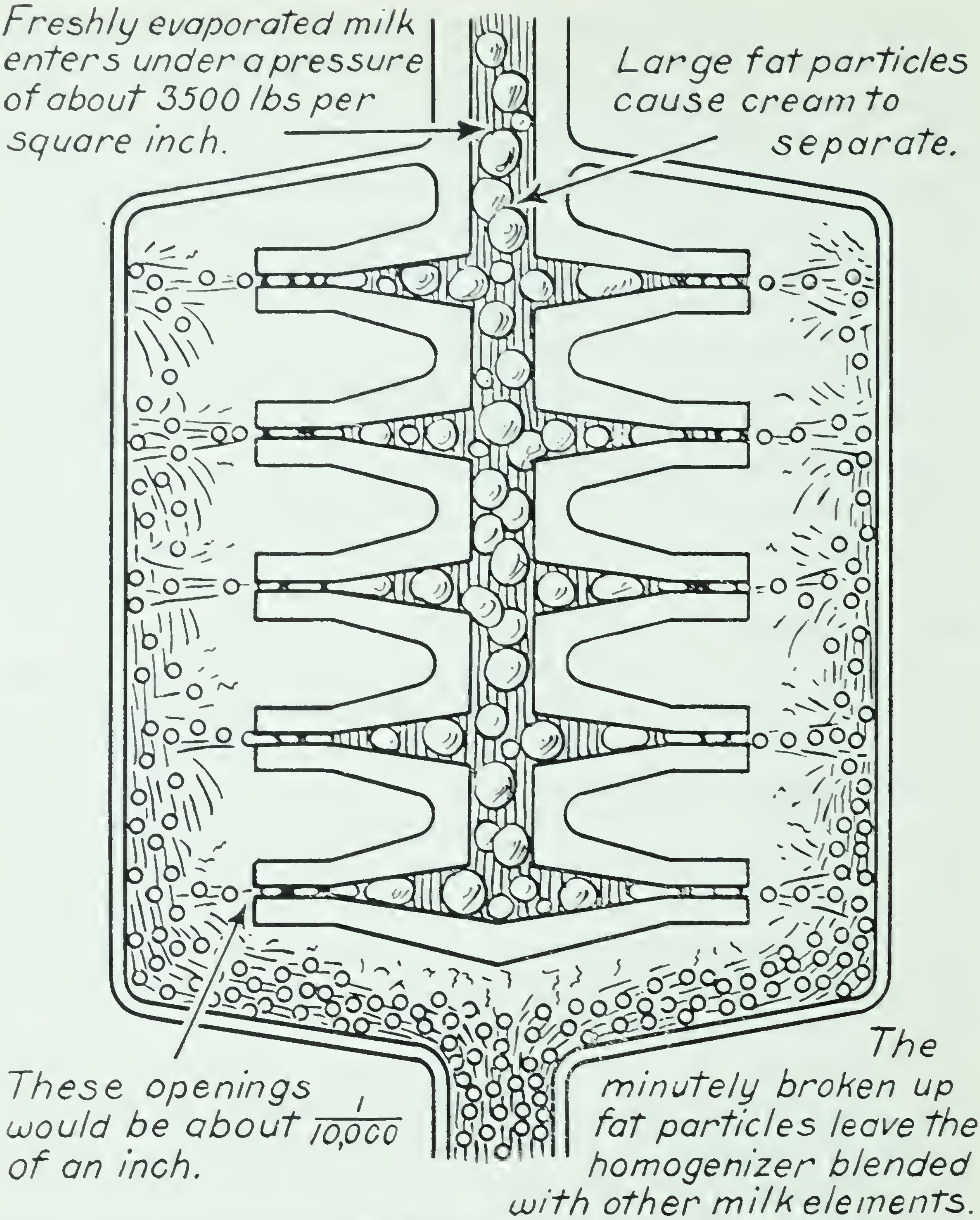
What suspensions do we use? Whenever you see on a bottle, "Shake well before using!" you have a suspension in the bottle. One of the characteristics of suspensions is that the particles of matter are so large that they tend to settle out of the liquid. Suspensions are thicker at the bottom than at the top of the liquid. They usually may be made clear by pouring them through filter paper.

Muddy water is a natural suspension. The lower Mississippi Valley was formed by the settling of suspended solids.

Milk of magnesia, familiar to many children, is a suspension. Many other medicines have at least part of the material in suspension. Shoe white, poster inks, India ink, and common paint are also suspensions. Tea and cider contain suspended particles.

Chocolate milk is a suspension that is treated electrically to cause the particles to push each other away instead of clinging together to form clumps of chocolate large enough to settle.

What are emulsions? According to an old saying, oil and water do not mix. But if we add soap or Dreft to the water and shake them together, the drops of oil are sur-



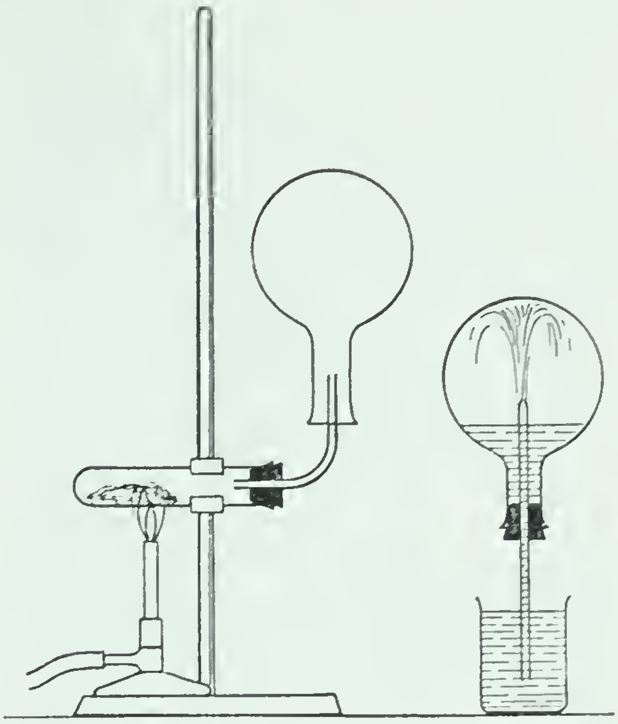
Courtesy Irradiated Evaporated Milk Institute

To keep fat in the emulsion in evaporated milk, the particles of fat are broken up.

rounded by a thin film which keeps them from getting together. Although the oil-and-soap mixture will finally rise to the top of the water, it forms a creamy mixture instead of drops of pure oil. Such a mixture is called an emulsion. Dishwater is commonly an emulsion because it contains soap and grease from dishes.

Gravy and mayonnaise are emulsions in which starch or egg is used to keep the oil particles apart. Some salad dressings are more like gravy than they are like mayonnaise, because they contain starch instead of egg.

What is milk? Milk is a complex liquid. It is an emulsion of butterfat, for the fat remains in the milk for many hours. It is a suspension of the protein solids, which settle out as the milk sours to form the curd. It is a solution of sugar and minerals. When the milk sours, the solution of sugar changes to a solution of lactic acid.



Ammonia gas is made by use of the apparatus at the left. The gas is collected in the flask, which is stoppered and used to make the fountain shown at the right.

Demonstration. What Are Some Common Liquids?

What to use: Dry flask, one-hole stopper and jet tube, test tube with stopper and delivery tube, ammonium chloride and calcium oxide, ring stand and burner, phenolphthalein powder, alcohol, funnel, filter paper, stand, test tubes, soap, oil.

What to do: Set up the apparatus as shown in the first part of the diagram. Prepare a phenolphthalein solution by putting as much of the powder as will stay on the point of a penknife in the beaker. Wet it with a little alcohol, and fill the beaker with water. Put a spoonful each of ammonium chloride and calcium oxide in the test tube as shown. Heat it gently, collecting the gas. When the flask is filled, put the stopper and jet tube in and put the end of the tube in the beaker, as shown in the second part of the diagram. Phenolphthalein is an indicator, similar to litmus.

Filter a solution of salt water and a suspension of muddy water, and determine which type of material goes through a filter.

Make an emulsion of soapsuds and oil, and compare it with a suspension of oil in water.

What was observed: Describe the results from each part of the demonstration.

What was learned: What chemical change took place to produce ammonia? Is ammonia soluble in water? What color is phenolphthalein in the presence of a base? What forces water into the flask? Can suspensions be filtered clear? Solutions? Describe an emulsion.

Exercise. *Make a table by ruling your paper into four columns. Head the columns as follows:* ELEMENTS AND COMPOUNDS, SOLUTIONS, EMULSIONS, SUSPENSIONS. *In the correct column write the following words:* coffee, ink, milk, gasoline, shoe white, carbon tetrachloride, bluing, paint, pop, ammonia, dishwater, perfume, gravy, mercury, milk of magnesia, iodine, pea soup.

Science activity. Put some muddy water in a glass, and let it stand until the water evaporates. Explain the appearance of the glass.

8. How do we obtain energy from fires?

When any type of change in matter takes place, there is a corresponding change in the amount of energy present. Some changes occur only when energy is supplied from another source, while other changes go on when once started, and at the same time give off energy. A fire is the latter type of change. Because fires are easily controlled, they are our largest single source of useful energy. To start a fire it is necessary to have a fuel, oxygen, and some method of raising the temperature of the fuel to its kindling point.

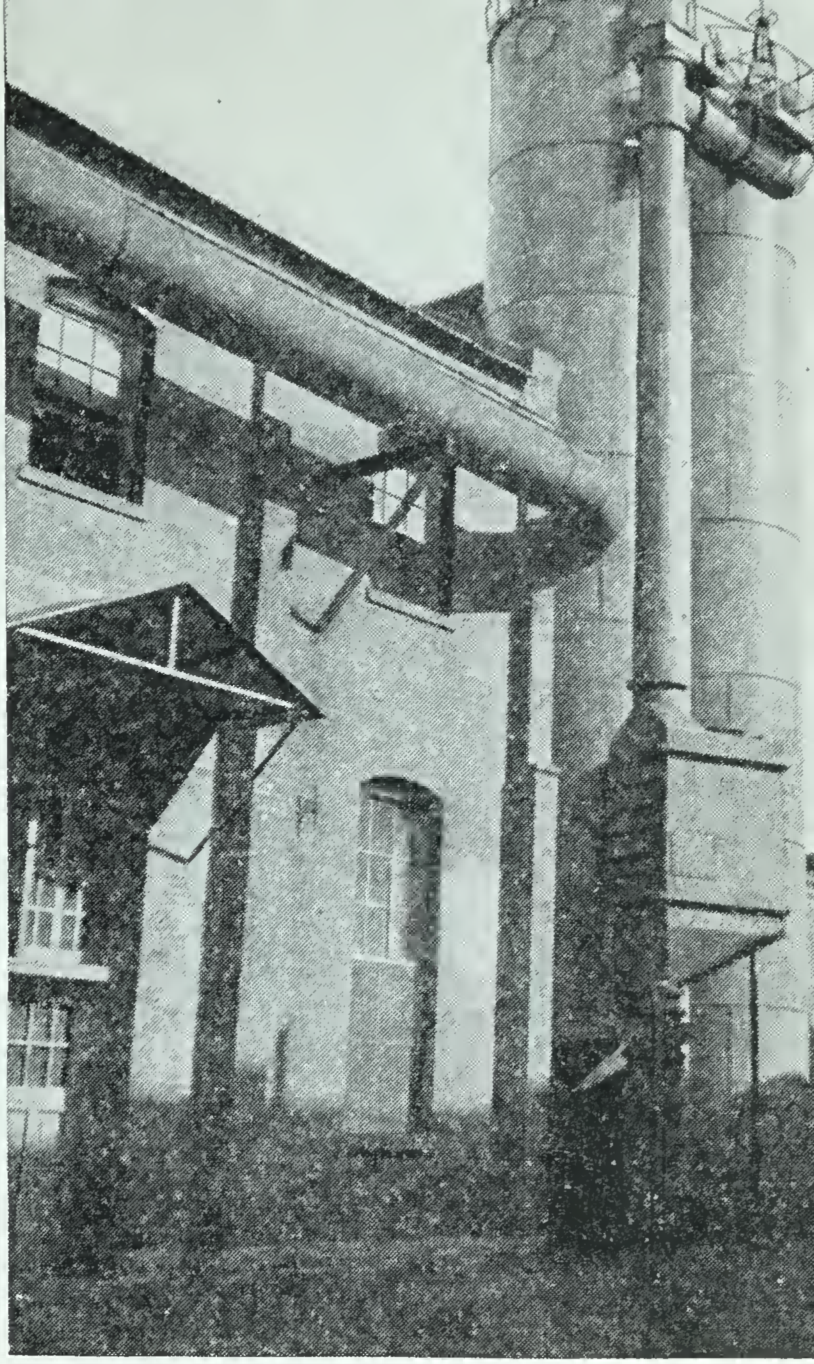
What are the common fuels? There are four kinds of fuel in general use: wood, coal, natural gas, and oil. Each of these may be made to yield fuels other than those produced by nature.

A fuel is a combustible (capable of burning) material which is plentiful enough to be cheap and which is easily handled and controlled in use.

Among the best fuel woods are the hardwoods, oak and hickory; and the softwoods, pine, fir, and tamarack. The hardwoods burn with a steady slow heat and produce lasting coals. The softwoods contain more resin and make a hotter, quicker fire. Pitchy softwoods are excellent kindling fuels.

Charcoal is an excellent fuel for broiling steaks and for heating kettles in the fireplace. It is prepared by starting a fire, covering it with wood, and then covering the wood with earth. The smoldering fire produces charcoal. It is possible to make a fairly good grade of fuel gas from wood.

There are various grades of coal used for fuels. The common coal is bituminous, or soft coal. It is made of carbon and various hydrocarbons, materials which are chemical compounds of hydrogen and carbon. Anthracite, or hard coal, is more nearly pure carbon than is soft coal. Because of this fact, hard coal burns with a slower, cleaner flame than does soft coal. In some regions peat, which is a partially formed coal, is burned as a fuel. Lignite coal is between peat and soft coal in its structure, being brownish-black and somewhat woody.



When gas is made from coal, it contains sulphur, ammonia, and other impurities which would clog pipes and make unpleasant odors in the home. These impurities are removed by a spray of water which washes the gas flowing through the towers.

Coal is the raw material from which we manufacture two most important fuels: coal gas and coke. Both are produced by the same process. The soft coal is heated in a furnace with an insufficient supply of air, so that burning is incomplete. The gas formed is carbon monoxide (CO). This gas, which is poisonous, is burned in the gas stove. There are various compounds of hydrogen and carbon added to manufactured gas to make it hotter. Another gas with a bad odor is added to make us aware of the coal gas when it escapes in the room.

The coal gas is run through various towers and scrubbers where water is used to absorb and dissolve the sulphur, ammonia, and tars which come from the coal. Gas is stored in tanks until used. The solid material left behind is coke, which consists of the ash and carbon. As you know, coke is used both for a fuel and for manufacturing metals.

Natural gas is burned as a fuel—sometimes with little treatment, sometimes after the more explosive gases have been removed. Natural gas is generally cheaper than manufactured gas. It is composed of a mixture of compounds of hydrogen and carbon.

Crude oil is the source of the fuel oils, gasoline, and kerosene. The materials in crude oil boil at different temperatures. The first liquids which boil off in the refinery are the most explosive gases. The liquids are further distilled by heating them and collecting the vapors as they pass off. Each increase in temperature drives off a different type of hydrocarbon fuel. Kerosene, gasoline, naphtha, and benzine are some of the products which have fairly low boiling points. The heavier oils and fuel oil boil at higher temperatures. Finally there are left only the waxy paraffins and tars, which are next separated. The whole process of manufacturing fuels from crude oil is called refining.

It is doubtful that there is enough petroleum in the world to justify its continued use as fuel. Although new supplies are being discovered, the supply which is known to exist is sufficient to last only 10 to 15 years. Whether we can find satisfactory substitutes when the supply is eventually exhausted is a serious question.

What are the products and by-products of burning? When carbon burns, carbon dioxide is produced. Because all common fuels contain carbon, their flames contain carbon dioxide. When hydrogen burns, water is formed. Not all fuels contain hydrogen in any large amounts. Charcoal and coke contain almost none. Water, then, may or may not be a product of burning.

When wood burns, water is released, and carbon dioxide forms. The water is chemically part of the wood.

There are several products of partial burning. One of these is smoke. Smoke consists of any solid or liquid fuel material

Courtesy U. S. Bureau of Chemistry and Soils

Burning releases energy. An explosion of grain dust in this 10,000,000-bushel elevator killed six people, injured four others, and caused a property loss of $3,750,000.

which cools before the process of burning is complete. Smoke contains carbon, tars, and oil. Another product of incomplete burning is carbon monoxide, which forms in gasoline engines used on the farm pump and washing machine, in the automobile, and in stoves which have insufficient draft. Since this gas is colorless, odorless, and tasteless, and a deadly poison, one cannot be too careful to guard against its dangers. Broken exhaust pipes, closed garages, and close rooms are particular sources of danger.

A by-product of burning which is released from the fuel is ash. Wood ash contains the minerals taken from the soil by the plants. Coal contains particles of soil and rock, as well as the more usual ash materials. These materials often melt together to form clinkers in the furnace.

What energy is released by burning? Energy released by burning comes from the sun and is stored in the fuels. The energy is released in the form of heat or infrared rays, as the result of a chemical change.

Fires also heat materials produced by burning to temperatures sufficiently high that they give off light. The flames of the kerosene lamp, the candle, and the wood fire get their yellow color from the glowing particles of heated carbon which they contain. Fire is used for heat more often than for light.

Demonstration. What Materials Are in Coal?

What to use: Test tube, stopper, L-shaped delivery tube with end drawn to jet, coal, ring stand, clamp, burner, litmus paper.

What to do: Put some coal into the test tube, holding the tube almost level with the clamp. Put the stopper into the tube, with the jet tube pointing upward. Heat the coal for some time. Test the escaping gas with wet litmus paper. Light the gas which comes from the jet tube.

When action stops, break the test tube. Examine the solids remaining. Smell and examine the tarry materials in the tube. Hold a piece of coke in the flame to see how rapidly it burns.

What was observed: Describe the appearance of the materials driven from the coal by heat. What is left behind?

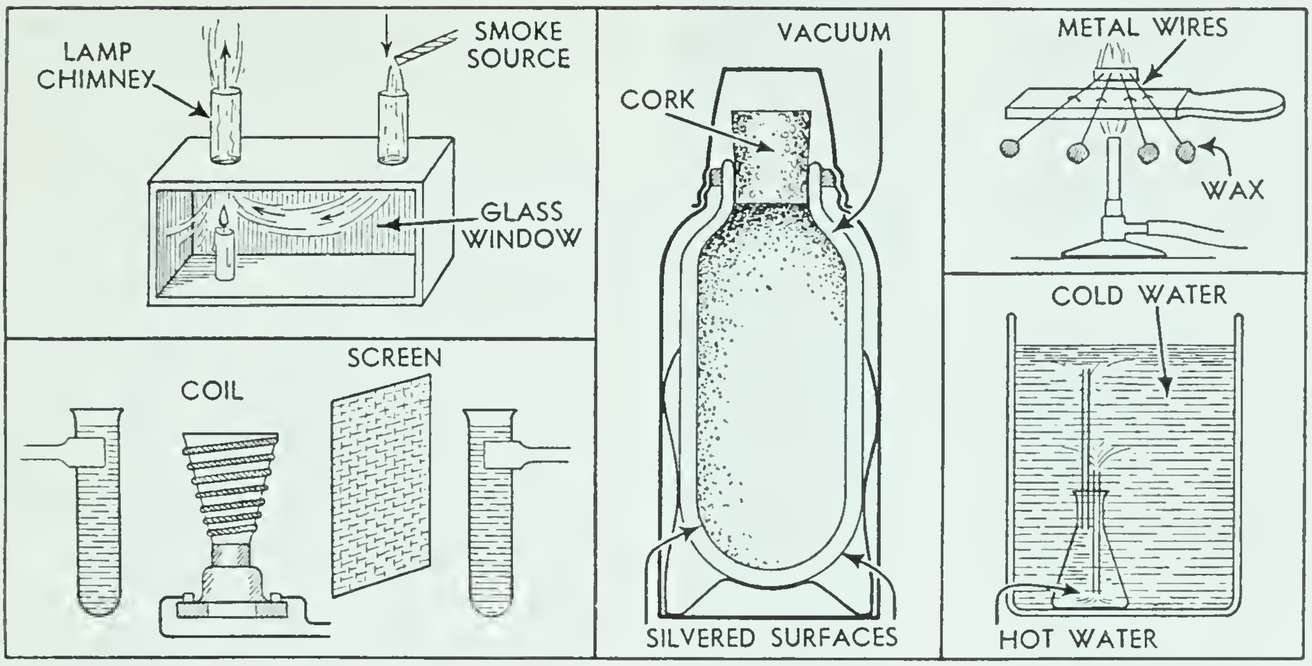
What was learned: What materials are in coal?

Filmstrip: Fire and fuels. S.V.E.

Exercise. *Complete the following sentences:* To make a fire we must use a —1— substance which has been raised to its —2— in the presence of a supply of —3—. Useful combustibles are called —4—. Coal is composed mostly of —5—, but contains also —6— and —7—. Poisonous —8— results from partial burning. Unburned materials in fires are —9— and —10—. Solids left behind after complete burning are —11—. Fires give off energy in the form of —12— and —13—.

Science activities. 1) You can distill coal by putting it in the fire in a clay pipe, sealing the bowl with clay. The gases issue from the stem, and coke is left in the bowl.

2) Make a collection of fuels, including at least three kinds of



The smokebox illustrates convection of gases. The coil and test tubes illustrate heat transference by radiation. The screen stops radiant heat. The thermos bottle delays transfer of heat by all three methods. The wires conduct heat at different rates. The flask and jar of water illustrate convection of liquids.

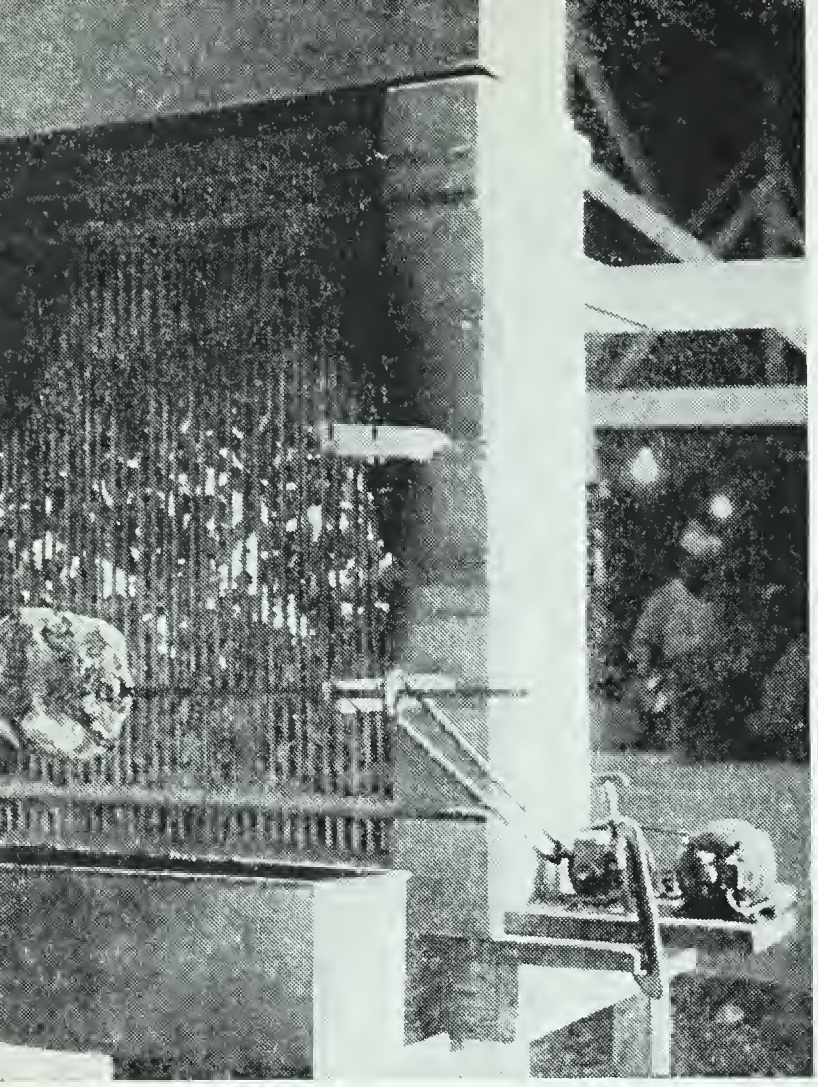
coal, briquettes, fuel oil, and three hard and three soft woods. Display them on a board.

9. In what three ways may energy be carried?

Energy may be carried from one place to another by radiation, conduction, and convection [kŏn·vĕk′shŭn]. Some forms of energy can be carried by all three methods, some by two methods, and some forms by only one method.

What is radiation? When energy travels by radiation, it moves in straight lines, usually at the speed of 186,240 miles per second. Radiant energy can travel through vacuums. Air and glass permit light and heat to pass through practically unchanged.

Radiant energy travels from the sun to the earth, a distance of 93 million miles, in about eight minutes. This radiant energy consists of ultraviolet rays, light, infrared or heat rays, and radio waves. The energy of the sun which strikes the earth is either absorbed or reflected back into space. If energy is not reflected immediately, it is absorbed and changed to a different form of energy, usually heat or infrared rays, and again radiated into space. Radiation of heat from



Radiant heat from the glowing charcoal cooks the ham as it is slowly turned by the motor. Why is it unnecessary for the ham to be above the fire?

the earth goes on all the time. Energy from the sun is taken in only in the daytime.

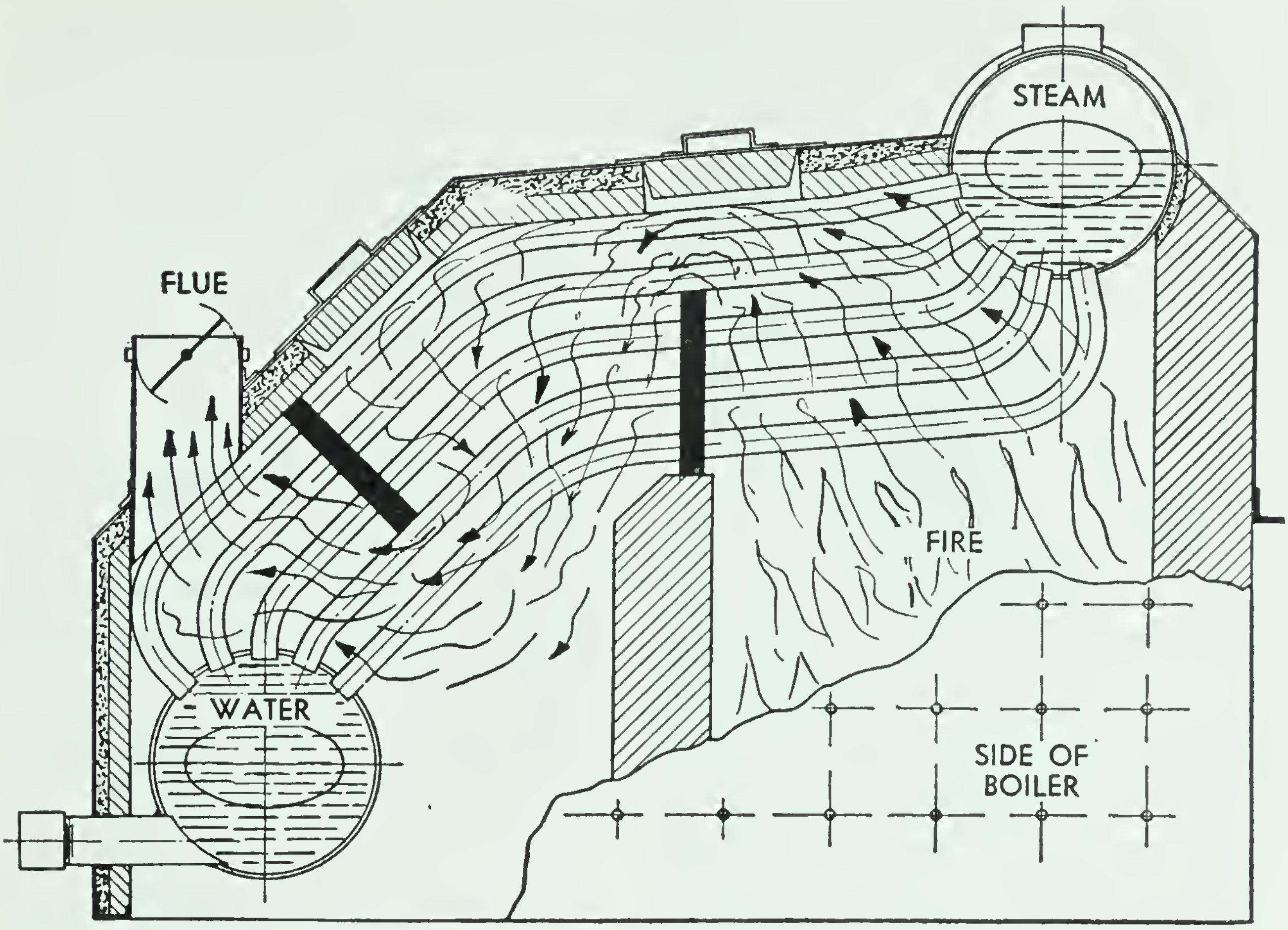
Radiation takes place fastest from bodies having the greatest amount of energy in them. A red-hot iron radiates its heat faster to the air than does a cooler piece of iron. Radiation takes place faster from large surface areas than from smaller surface areas. Radiation takes place faster from dark than from highly polished or light-colored objects. In the opposite way, radiant energy is absorbed faster by cool objects having large surfaces which are dark in color.

What is conduction? There are several forms of energy that travel by conduction. Mechanical energy, heat, sound, and electricity are usually conducted from one place to another.

Mechanical energy is carried by conduction when a passing truck rattles the dishes on the table. The energy is carried by the vibrations passing along from one particle of matter to the next.

Heat is conducted by matter. If you put the bowl of a silver spoon in hot tea, the handle becomes hot. The molecules of silver vibrate more rapidly as they take in energy and bump each other, passing the energy along from the bowl to the handle. An iron poker, one end of which is in the fire, becomes too hot to hold. A flat iron on an iron stove is heated by conduction.

Electricity is carried by conduction along wires, and to some extent by moist air and liquids. Sound is conducted by the bumping of molecules of air, water, or any solid against each other.



Courtesy Murray Iron Works

The drafts of the fire are convection currents. The circulation of water in the pipes of the boiler is another form of convection. This type of boiler generates steam for heating and for engines.

Conduction is different from radiation, in that energy follows along the material conducting it instead of going in straight lines. Conducted energy may travel slowly. It takes several minutes to heat a flat iron on a stove.

Some materials are good conductors of energy; others are poor. Heat travels rapidly in copper, silver, and aluminum, and fairly rapidly in iron. Stone, brick, and glass conduct heat poorly compared to metals, but well compared to wood, paper, cloth, and air. When several objects are equally warm, the best conductor feels hottest to the touch. When the objects are cold, the best conductor feels coldest. On a cold day, during freezing weather, if one touches a piece of iron, the hands may stick to it. The iron conducts heat away so rapidly that the moisture on the hand freezes.

Electricity travels well in metals, poorly in cloth, rubber, wood, and dry air. Sound travels best in solids, and most poorly in gases.

What is convection? Convection is a special way of transferring heat. As you know, when matter is heated it expands, and a given volume becomes lighter in weight. When matter is free to move, as is the case with gases and liquids, the lighter, warmer gas or liquid rises, and the cooler falls. In the world wind system, in circulation of air in a room, and in the hot-water tank and large electric light bulbs there are gases or liquids circulating.

As these materials circulate, they carry heat with them. For example, the air over a hot stove rises because it is heated. The circulating air may strike the cold ceiling where it gives off its heat. The gas then contracts, becomes heavier per unit of volume, and falls. The circulation and transfer of heat in gases and liquids is called convection.

Convection is different from conduction in that in convection the heated material itself actually moves, while in conduction the matter remains stationary, and the energy travels from one part to another. Convection takes place only in liquids and gases. The best conductors are generally solids.

Why does the vacuum bottle hold heat? The vacuum, or thermos, bottle is one of the best devices commonly used to prevent heat loss. When we put our food in a vacuum bottle, we expect it to remain at about the same temperature for hours.

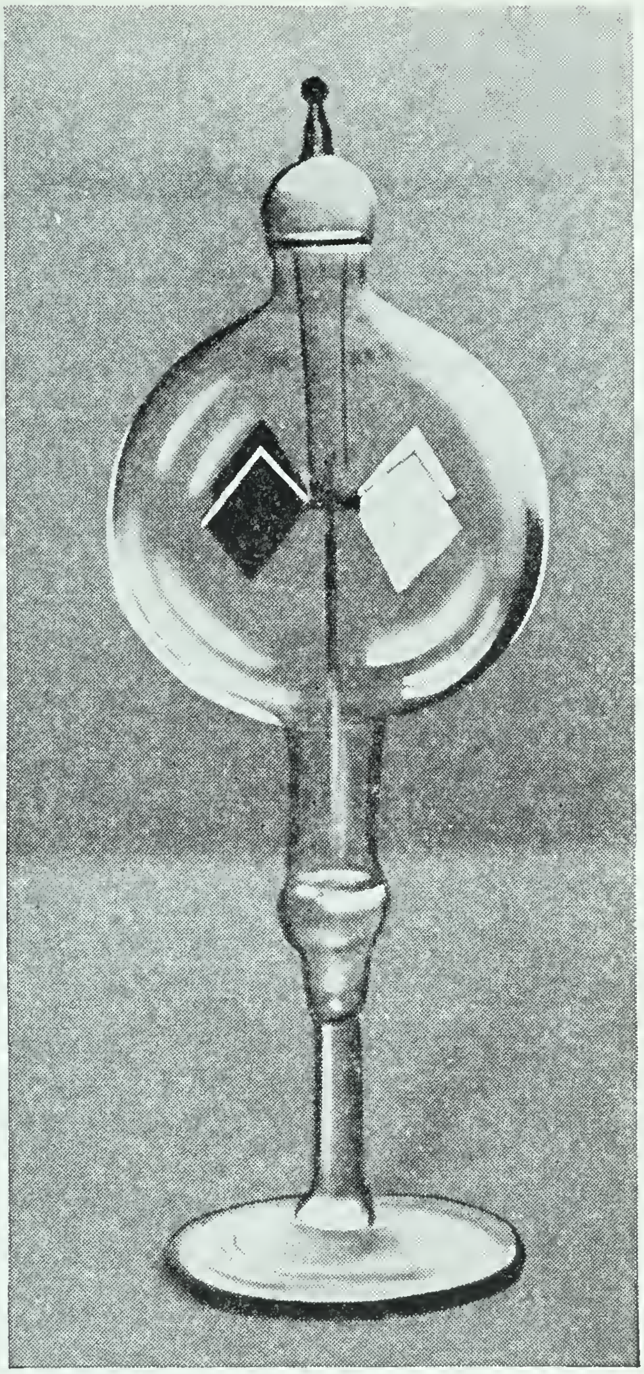
The vacuum bottle is really two bottles, one inside the other. The two are sealed together at their necks, and the space between is made a vacuum by pumping out the air. The surfaces of the two bottles which face each other are silvered. The bottle has a cork stopper and is enclosed in a case. A spring supports the bottle and absorbs shocks.

The vacuum between the bottles prevents loss of heat by conduction. The silvered surfaces reflect the radiated heat into the bottle. There are no gases between the bottles to carry heat by convection. The greatest loss of heat takes place around the cork stopper.

Vacuum bottles are used for carrying liquid air which boils violently if warmed. Some railroad tank cars are huge vacuum bottles. Cooled milk keeps for many hours in such cars.

How does the radiometer work? The radiometer [rā′ dĭ·ŏm′ė·tēr] is a device made up of four vanes supported on a needle point. The vanes are silvered on one side and black on the other. They are enclosed in a bulb inside which is a partial vacuum. The radiant energy of the sun heats the black surfaces more than the silvered surfaces. The molecules of the black material strike or bump the molecules of air in the bulb with more force than do the molecules of silvered material. The vanes turn around rapidly in bright sunlight, and slowly in dim light, always as if they were being pushed on the black side.

The radiometer illustrates the principle that black surfaces absorb more heat than do light surfaces, and the principle that molecules have energy in proportion to their temperatures.



A radiometer consists of vanes mounted on a needle point within a partial vacuum. The vanes turn when light shines upon them.

Demonstration. How Is Energy Carried From Place to Place?

What to use: Smokebox, 2 lamp chimneys, candle, touch paper, Erlenmeyer flask, glass tubing, stoppers, battery jar, coloring matter, Bunsen burner, conduction apparatus, electric heating coil, test tubes, cardboard, thermometers.

What to do: Set up the smoke box, as shown at the top left on page 145, and test the currents of air at both chimneys.

Fill the flask with nearly boiling colored water, put in the

stopper and tubes as shown in the diagram on page 145 (*bottom right*), and put it quickly into the battery jar of cold water.

Dip each of the four wires in melted wax. When a drop of wax forms on the ends of the wires, heat them as shown in the diagram at the top right on page 145.

Set up the coil, cardboard, and test tubes as shown on page 145 (*bottom left*). Measure the temperature of the water at the beginning of the experiment and after 10 minutes.

What was observed: Describe what happened in each demonstration. What principles are illustrated by each demonstration?

What was learned: Explain radiation, conduction, and convection.

Exercises. *Make a table by ruling your paper into three columns. Head the columns as follows:* RADIATION, CONVECTION, CONDUCTION. 1) *Each of the following is connected with one of the methods of heat transference. List them under their proper headings:* sunburn, wind, glare, hot spoon handle, cold linoleum, ventilation, burning glass, fire drafts, hot-water bottle.

2) *Each of the following methods is used to prevent heat from being carried by one of the three methods. List them under their proper headings:* cork in icebox walls, polished water pipes, vacuum in bottle, strips around cracks in windows, wooden handle on poker, aluminum foil in walls.

Science activity. In one of the older science books look up the fireless cooker, and construct a model. Explain how it works.

10. How do we measure changes in heat energy?

The amount of energy that can be obtained from any fuel or from any chemical change must be measured accurately before we can know much about what results to expect from the fuel or from the change. Of course burning does not release all the energy in matter.

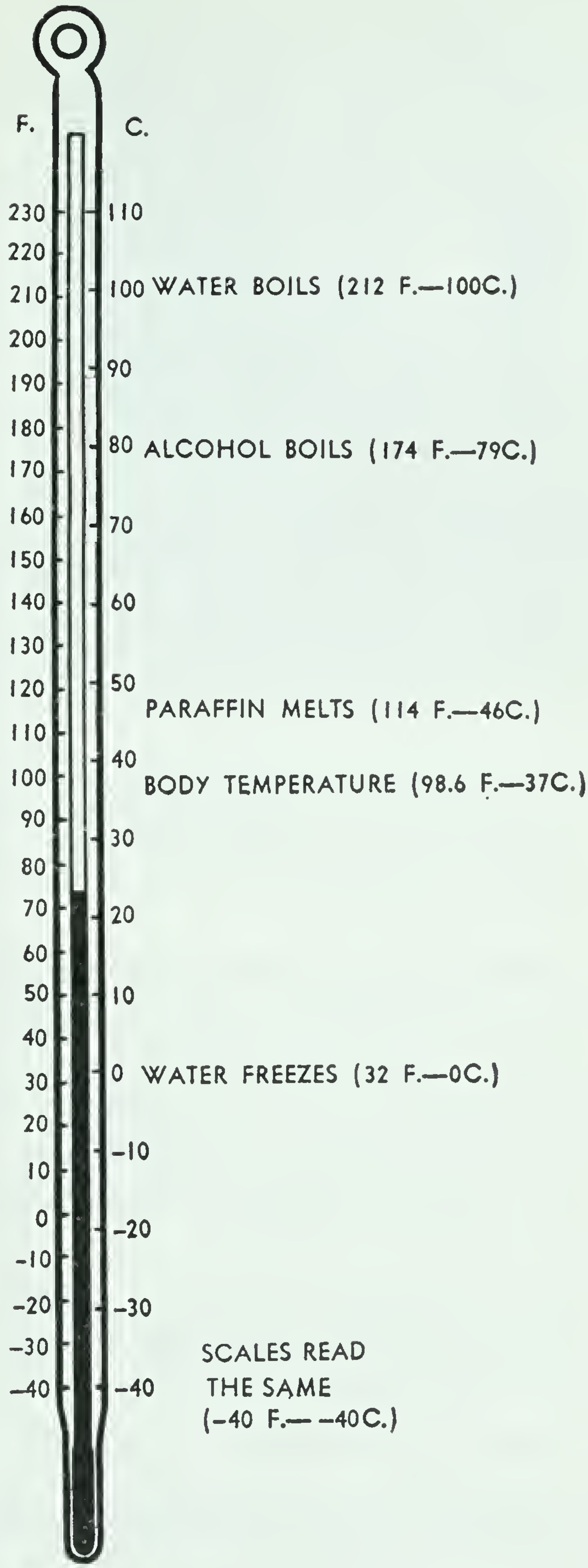
We have no ordinary device which will measure heat directly. We measure the amount of heat that we can obtain from fuels indirectly.

How do we measure temperature? We measure temperature by use of the thermometer. The first thermometer was the air-bulb thermometer invented by Galileo. It consists of a bulb and tube, inverted in a container of water. When the air is heated sufficiently a few bubbles escape. When the

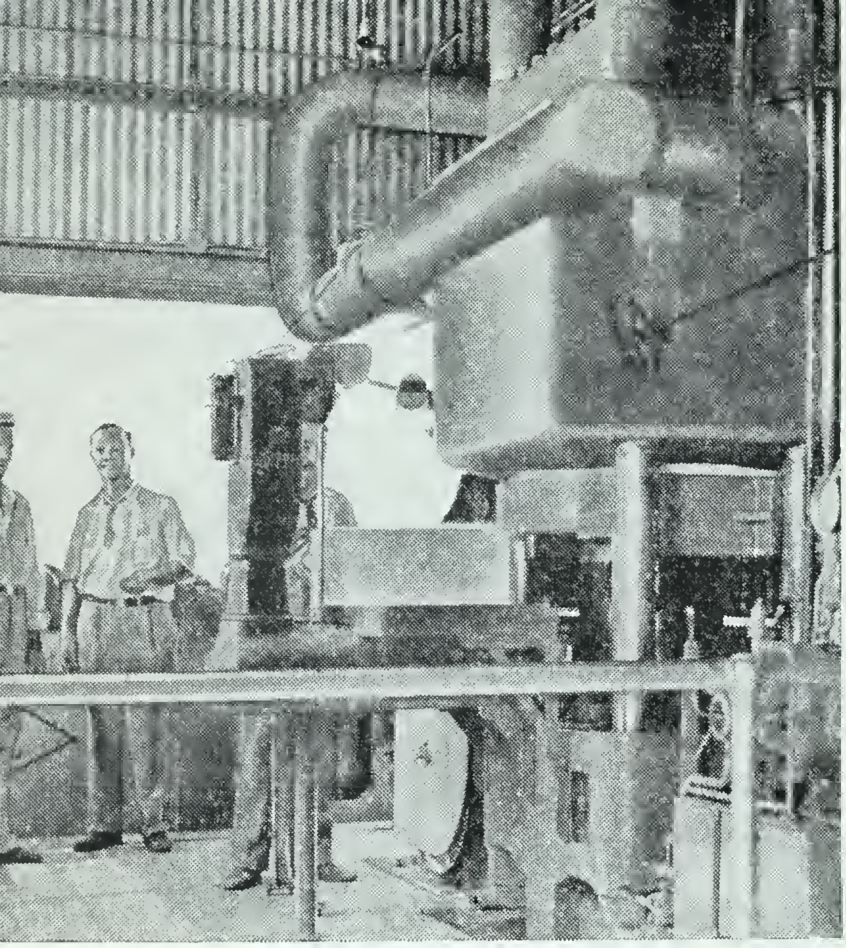
air is cooled, it contracts, and water enters the tube. The height of the water in the tube at room temperature depends chiefly upon the temperature of the air in the bulb.

Our ordinary thermometers depend upon the same principle of expansion and contraction, except that the bulb contains mercury, alcohol, or some other liquid instead of air. The tube is sealed, and generally contains no air. Mercury has the advantage of not boiling at ordinary temperatures encountered in the laboratory or home. It freezes at about 40 degrees below zero, and is not satisfactory for use in outdoor thermometers in very cold regions. Because alcohol has a low boiling point and a low freezing point, it makes the best liquid for the outdoor thermometer in very cold weather. Alcohol is generally dyed so that it can be more easily seen.

What are the Fahrenheit and centigrade scales? The fixed points for marking scales on a thermometer are the freezing and boiling points of water. There are two common scales of



Compare the temperatures on the two thermometer scales at which the scales read the same. What is room temperature on each scale? Which thermometer scale has longer degrees?



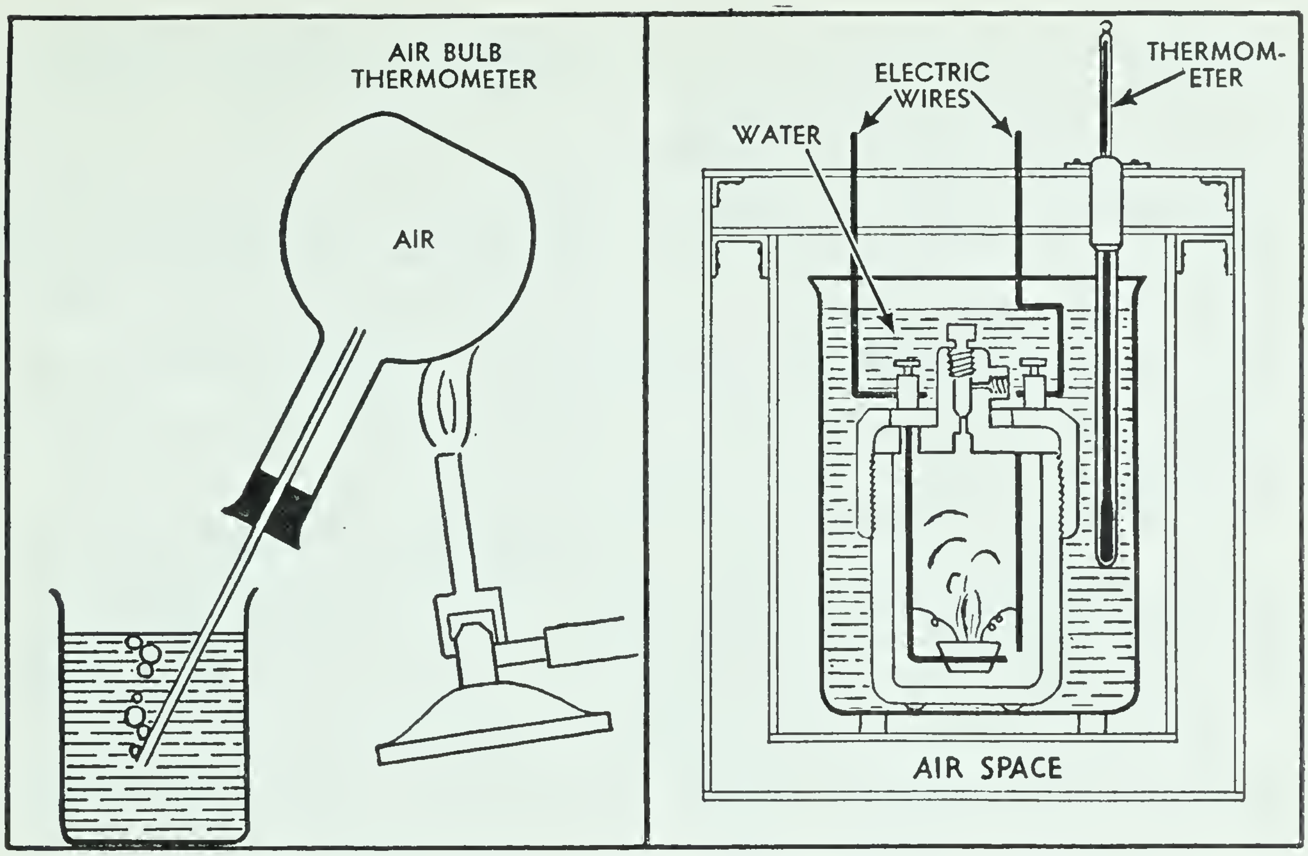
Courtesy The Hydraulic Press Mfg. Co.

A cake of dry ice, which is solid carbon dioxide, comes from the hydraulic press. Although dry ice seems very cold, it still contains considerable heat.

units for measuring temperatures. The common scale in English speaking countries is the Fahrenheit. The most common in all other countries and in all science laboratories is the centigrade. The U. S. Weather Bureau, however, keeps all its records in the Fahrenheit measurements.

The scale of a thermometer is made by marking the freezing point at which the mercury stops falling when the thermometer is placed in ice water. The boiling point is marked where the mercury stops rising in boiling water at sea level. If the boiling point is marked at elevations higher than sea level, allowance must be made for the difference in boiling point. Between these freezing and boiling points, which are called fixed points, the scale is marked. If the thermometer is centigrade, the distance is divided equally into 100 degrees. If the scale is marked in the Fahrenheit system, it is divided into 180 degrees, and an additional 32 degrees are added to establish a zero. A Fahrenheit degree equals 5/9 of a centigrade degree. The freezing and boiling points of the centigrade thermometer are 0 and 100, those of a Fahrenheit scale 32 and 212. Temperatures on one scale can be changed to temperatures on the other by use of the formula: $\frac{C}{F-32}=\frac{5}{9}$.

What is the difference between heat and temperature? Heat and temperature are not at all the same. Heat is the energy present. Temperature is a measure of whether a given object will give off or take in heat compared to another object. When one says that a certain object is cold, he means that his body gives off heat to the object. When the object seems warm it gives heat to the body. If an object is warm,



The effect of temperature changes in causing expansion and contraction of matter provides an indirect way of measuring temperature. Heat is measured by burning fuel or by placing a hot object in the container surrounded by water.

it also gives heat to a thermometer, until the thermometer will absorb no more heat. The mercury in the thermometer expands with the increase in temperature when heat is taken in, until the two are of equal temperature. That is, neither gives off heat to the other. If the thermometer is warmer than the object, heat is given off by the thermometer, and the mercury contracts.

Heat may be added to some substances without causing any change in temperature. When heat is added to ice, the ice melts but does not become warmer. When heat is added to boiling water, the water changes to steam but does not change temperature. Similarly, heat may be taken from steam or water under proper conditions without lowering the temperature.

How is heat measured? When heat is added to water, the temperature of the water is raised. There are two different units of measuring heat. One, the British Thermal Unit, abbreviated B.T.U., is the amount of heat required to raise one pound of water one degree Fahrenheit. The other unit,

the calorie, is the amount of heat required to raise one gram of water one degree centigrade. The large calorie, or food calorie, is 1000 small calories.

The simplest way to measure the amount of heat in a hot object is to put it in cool water of known temperature and to measure the increase in the temperature of the water. Then by multiplying the weight of the water by the change in the temperature, we have a measure of the amount of heat lost by the object.

To measure the amount of heat given off by burning materials, a calorimeter [kăl′·ȯ·rĭm′·ė·tẽr] (*see diagram on page 153*) is used. It consists of an inner vessel in which the fuel may be burned in a supply of oxygen. The fuel is set on fire by use of a wire heated by electricity. The heat is taken up by water in a second container which surrounds the first. The weight of the water and the change in temperature are measured. The two multiplied together give the number of heat units given off by the fuel. Allowance is made by reference to tables for the heat taken in by the metal containers.

Use of this device for measuring the true value of fuels saves thousands of dollars yearly. Fuel value of foods is also determined by burning dried samples in the calorimeter.

The approximate amount of heat in fuels is shown in the following list.

Fuels	*B.T.U. per pound*
Oak wood	8,000
Peat	7,000 to 9,000
Charcoal	12,800
Soft coal	11,700 to 14,000
Hard coal	12,500 to 14,500
Fuel oil	18,000

The actual value of fuel is determined, not only by the number of heat units per pound, but by the cost of the fuel and by the amount of heat that can be obtained from the fuel by burning it in a furnace. Oil can be burned somewhat more completely than can most coal, but it also costs more. Hard coal costs more than soft coal. In most parts of the United States, and under most conditions, soft coal supplies

the most energy per dollar. In some sections, where freight rates are high and other fuels are plentiful, coal may be too expensive for use in house heating. In these localities the cheapest source of heat may be gas, oil, wood, or electricity generated by water power.

Demonstration. How Is Heat Energy Measured?

What to use: Air-bulb thermometer, or flask with tube as shown in the diagram on page 153, beakers, piece of iron, ring stand and burner, balance and weights.

What to do: Put the end of the air thermometer tube into the water in a beaker, and warm the bulb with the hands. Cool the bulb, and observe the distance water rises in the tube.

Heat a piece of iron by putting it into boiling water in a beaker. Have ready a beaker containing 300 grams of cold water, with the temperature noted. Put the iron into the cold water, stir the water, and quickly note the increase in temperature.

What was observed: Describe the operation of the air-bulb thermometer. Calculate the number of calories carried by the piece of iron, by multiplying the weight of the water by the increase in temperature in centigrade degrees. Your results will be inaccurate. Why?

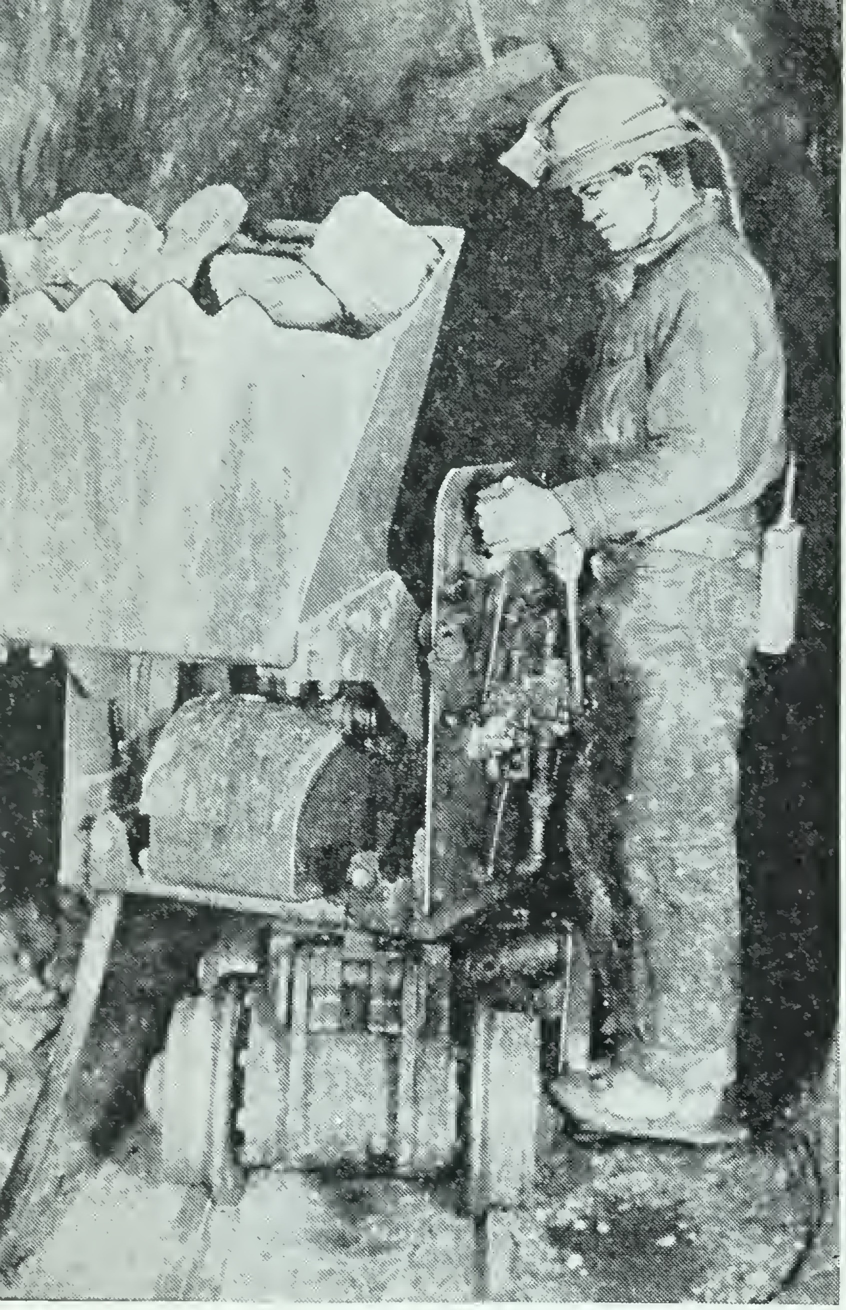
What was learned: What is the difference between heat and temperature?

Exercise. *Complete the following sentences:* —1— is the amount of energy in material, while —2— is a measure of relative hotness or coldness. We measure temperature by use of the —3—. A —4— is the amount of heat required to raise one gram of water one degree —5—. A —6— is the amount of heat required to raise one pound of water one degree —7—. The device in which fuels are burned to measure heat is the —8—. Energy in food is measured in —9— which are 1000 —10—.

Science activity. With a bottle, stopper, and glass tube make an air thermometer. Make a scale for it by comparison with a standard thermometer.

11. How do we obtain minerals from the earth?

Obtaining metals and other minerals from the earth is an important activity. The common minerals which we need for



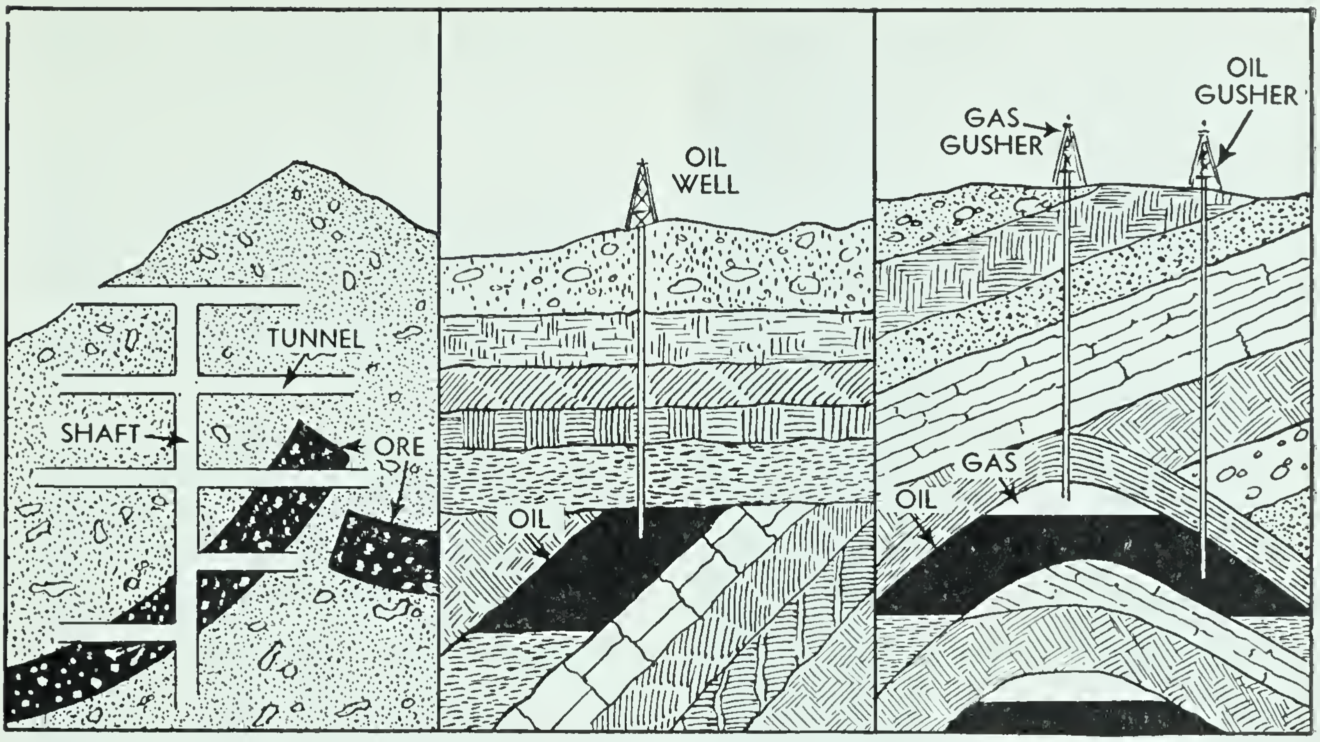
Courtesy Eimco Corporation

Much automatic machinery is used underground in collecting ores. This machine scoops up the ore after it has been blasted from the mineral vein.

our industries vary greatly in their scarcity and importance. Some of them are readily available. Sand, which is used in making glass, concrete, and plaster, is common everywhere. Iron is also commonly found in the rocks, but not often in form which is available for use. And aluminum, too, occurs commonly, but it occurs in forms which make it difficult to extract.

Most elements which occur in the earth's crust are so rare that they must be searched for with especial care to find them in sufficient quantities to provide for our needs. Such elements as copper, zinc, lead, gold, silver, mercury, and tin, for example, are not found in great abundance anywhere, and in many places are not found at all.

What common elements make up most of the earth's crust? Seven elements make up most of the rocks of which the earth's crust is composed. These elements are almost always found combined with each other or with other elements. One, oxygen, is free in the air; and another, iron, occasionally is found free. The rest are always found in combination. Aluminum is combined with silicon and oxygen in clay. Silicon is combined with oxygen in sand. Iron is found in the rust-colored rocks. Calcium is rarely produced in the free state, but occurs in the limestone rocks. The proportions of the common elements—oxygen, silicon, aluminum, iron, calcium, potassium, and sodium—in the earth's crust are shown in the following table:



The usual mine is dug into the earth. Oil may flow from wells where gas exists underground, but often it must be pumped from the ground. Oil is commonly held in porous rocks between layers of more solid rock.

Element	*Part of the earth's crust by weight*
Oxygen	One-half
Silicon	One-fourth
Aluminum	One-twelfth
Iron	One-twentieth
Calcium	One-thirtieth
Potassium	One-thirty-fifth
Sodium	One-fortieth

What are ores? An ore is any mineral from which a metal is extracted. At times the name ore is applied to other minerals from which nonmetals, such as sulphur, are obtained. Most common ores are chemical compounds of one or more metals with one or more of the acid formers—sulphur, chlorine, phosphorus, or oxygen. Some of the rarer elements form highly valuable ores.

Iron is found combined with oxygen to form different types of ores. Two common iron ores are called hematite and magnetite. Iron ores are brown or brownish-black in color, sometimes heavy and sometimes light and porous. In addition to the high-grade ores, from which a large amount of

iron may be removed, there are millions of tons of low-grade ores, from which enough iron cannot be obtained to pay for the cost of purifying the ore.

The chief ore from which aluminum is obtained is called bauxite [bôks′īt] and is a combination of aluminum, hydrogen, and oxygen. Most bauxite in this country is produced in Arkansas. Ordinary clay is not a practical ore, for there is no way of obtaining the aluminum from it.

Another of the important metals is zinc. It is obtained from the ore zinc blende, which is a chemical compound containing zinc and sulphur. Other zinc compounds are zinc carbonate and a compound containing zinc, silicon, and oxygen. The chief ore of mercury is also a compound of sulphur.

One of the most important of all metals is copper. Sometimes copper is found in its pure state, but usually it is obtained from ores which contain sulphur or carbon and oxygen in addition to the metal. Because of the brilliance of the blues and greens of some copper compounds, copper ores are the most beautiful found in the United States. Some copper ores are polished and used in making ornaments.

Gold and silver are not important metals, compared with zinc, copper, and iron. Of the two, silver is much more useful because of the amount needed in making photographic films and paper. Both gold and silver are found in an uncombined state, either as nuggets or as lumps in rocks. Silver is often found combined with other elements, gold rarely so.

What valuable materials are not obtained from ores? Coal and crude oil are among the most valuable of nonmetallic earth materials. Both were formed from living things of long ago. Coal is usually found in veins, where it was compressed by the weight of overlying rocks and soil. Oil is found only where there is an underground pocket from which it cannot float away on water. Such reservoirs are often dome-shaped. Oil may be found in the pores of sandstone or shale and held between water-tight rocks. It is probable that most of the oil which has been formed in the past has been lost, because it floats readily on water and evaporates into the air or is burned by fires.

Calcium compounds, chiefly calcium carbonate or limestone, supply materials for cement and lime. Sulphur is

found in the pure state in various places in the world, particularly in the lower Mississippi Valley in this country. Silicon compounds are used in making various materials needed in the building industry and in the construction of roads.

In the development of civilization, a silicon compound, flint, was the first material used for tools. Early man made from it knives, axes, spears, and fishhooks. Until recent times flint also was used to kindle fires.

What is mining? Removing minerals from the earth is called mining. There are several kinds of mining. The cheapest and most favored method where ores lie close to the surface consists of stripping off the upper soil and rocks and loading the ores directly into railroad cars with steam, gasoline, or electric shovels. There are several places in the United States where this method is possible. The largest mine of this type is an iron mine in Minnesota.

Courtesy Sullivan Machinery Company

Drills driven by compressed air make holes in the rock and ore. Blasting powder or dynamite placed in the holes explodes and loosens the mineral.

The more common type of mine consists of shafts or deep holes dug, drilled, and blasted into the earth. Such mines are often located in mountainous regions because here the minerals are nearer the surface of the earth and not buried under hundreds of feet of soil and rock. From the shafts tunnels are dug along the veins in which the ore is found. Copper, zinc, lead, silver, and coal are frequently mined by the deep-mine method.

Oil wells are not mines in the usual sense of the word, but really serve a similar purpose. If there is gas above the oil,

a gas well may result. If the gas pocket is not entered by the well, the gas may expand when pressure is released, forcing the oil from the well to form a gusher. If there is no gas, or if the gas escapes, oil flows into the well and is removed by pumping.

Salt and sulphur are pumped from wells. Water is pumped into the wells to dissolve the chemicals. In the case of salt, cold water may be used; but to remove sulphur, superheated water is used to melt the sulphur. The minerals and water are then pumped from the wells.

One of the most interesting and least important types of mining is placer mining. Free gold is heavier than other rock materials. If the mixture of gold and rock is washed with running water or by whirling it in a pan, the gold settles to the bottom. Sometimes the mixture is put into a box and rocked like a cradle. The lightweight rock is discarded, and the gold is kept.

DEMONSTRATION. WHAT ARE SOME COMMON ORES?

What to use: Washington or other mineral collection.

What to do: Select from the collection iron, copper, lead, zinc, and aluminum ores; and study them until you can describe their properties.

What was observed: Describe the appearance of each ore. Sketch the crystals if definite crystal form was observed.

What was learned: How can you distinguish the ores studied?

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* half, aluminum, oxygen, iron, one-fourth, silicon, calcium, sand, ores, oil, limestone, quartz, shaft, wells, placer, sulphur, copper.

12. How do we obtain metals from their ores?

When we have obtained the metallic ores from the earth, we still have a material far removed from its usable form. It is difficult to visualize a lump of brown rock as containing the polished steel of a razor blade, or a shining blue stone as part of an electric motor.

There are three general ways of obtaining metals from their ores: by use of electricity, by use of carbon to remove the oxygen, and by use of heat, or roasting. Some metals

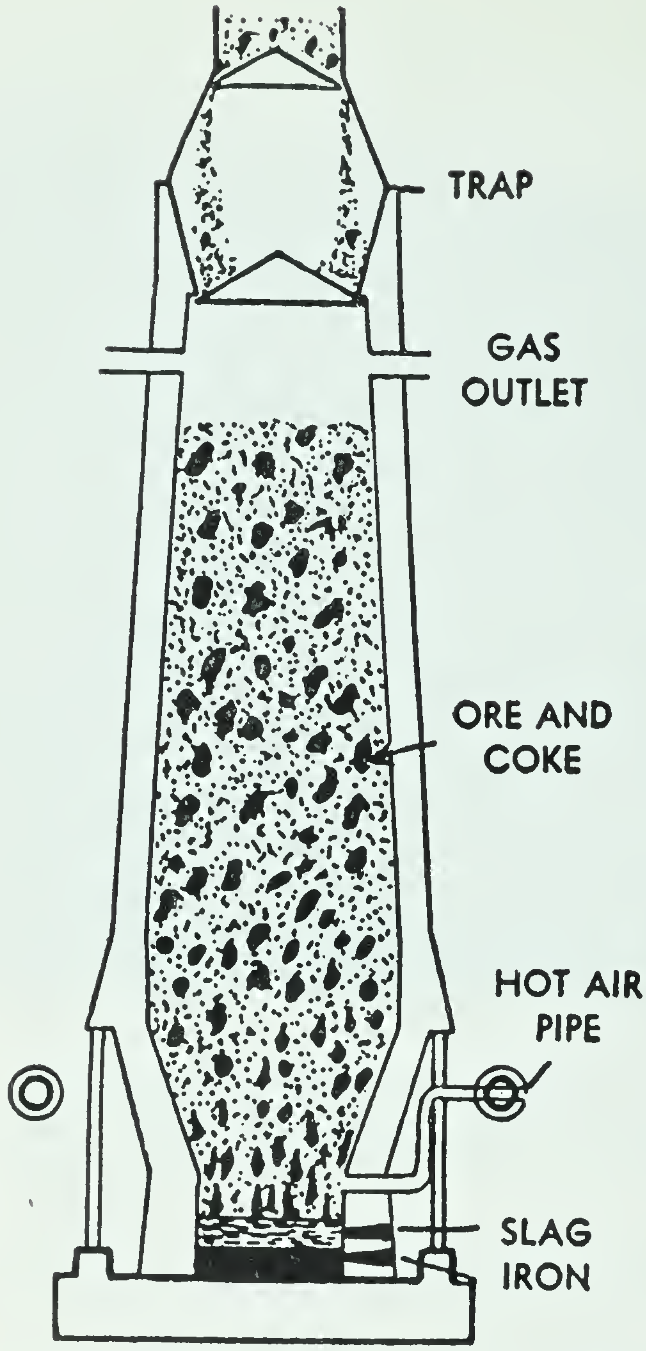
Courtesy Trinidad (Colo.) Chamber of Commerce

The part of a mine which shows aboveground consists chiefly of machines for moving the ore and of buildings which protect the machines. These buildings are located at the mouth of a coal mine.

may be purified by one of these methods; others must be purified by all three.

How is the blast furnace used? Metals in ores are separated from oxygen in the blast furnace. To purify iron ore, the ore, together with coke and limestone, is put into the furnace, which is a chimney perhaps 90 feet high. The coke burns to supply heat, and also reacts chemically with the ore, combining with the oxygen and leaving the iron free. Carbon dioxide and carbon monoxide are formed. To increase the temperature of the reaction, blasts of hot air are blown into the furnace through openings near the bottom. The chemical equation for purifying a typical iron ore is $Fe_2O_3 + 2C \rightarrow 2Fe + CO + CO_2$.

The melted metal runs to the bottom of the furnace, where it is drawn out through a hole. The impurities, along with the melted limestone, float as slag on the iron and are drawn



This diagram shows the construction of a blast furnace.

out through another hole. The blast furnace is kept in operation for months without stopping.

The iron is run into molds made of sand, and cools to form pigs. Pig iron is more than 90 per cent pure iron. Impurities are carbon and sometimes sulphur and phosphorus.

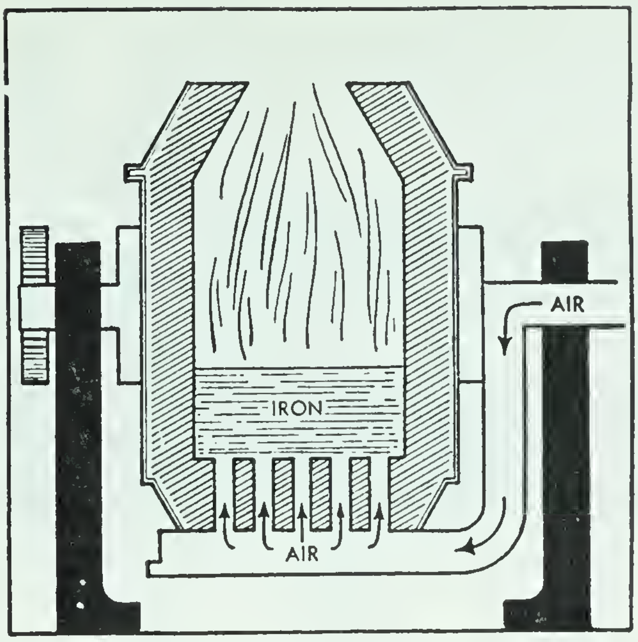
What is roasting? Platinum, mercury, silver, and gold may be separated from their ores by heat alone. Ores of other metals which contain sulphur are commonly heated to a high temperature to drive off the sulphur. The remaining ore is then purified by removing the oxygen by use of coke in a blast furnace. Some ores containing carbon dioxide in chemical combination with the metal are also purified by heating to drive off the gas. The resulting ore is an oxide which may be reduced in the blast furnace. Zinc, copper, and lead ores are treated by roasting before being reduced in a furnace.

When is electricity used in separation of ores? Five metals—potassium, sodium, calcium, magnesium, and aluminum—are purified only by the use of an electric current.

Under certain conditions electricity may be used in the purification of any metal. Copper is generally purified by use of electricity as the final step of preparing it from its ore.

What does the converter do? When it is formed into pig iron, iron contains considerable carbon. To remove the carbon, the iron is poured from the blast furnace directly into a converter, or the pigs are remelted, usually by heating with

coke or with an electric current. Blasts of hot air are blown through the melted iron in the converter. The air burns out the carbon and sulphur, and the impurities pass into the air in a spectacular flame. The operation must be controlled rather exactly and stopped at the right time, or the iron too will combine with oxygen and change back to ore.



Air blown through the melted iron in the converter burns out many impurities.

There are a number of different types of converters in use. The original converter was developed by Bessemer. This furnace is used today for making much of the steel used in industry.

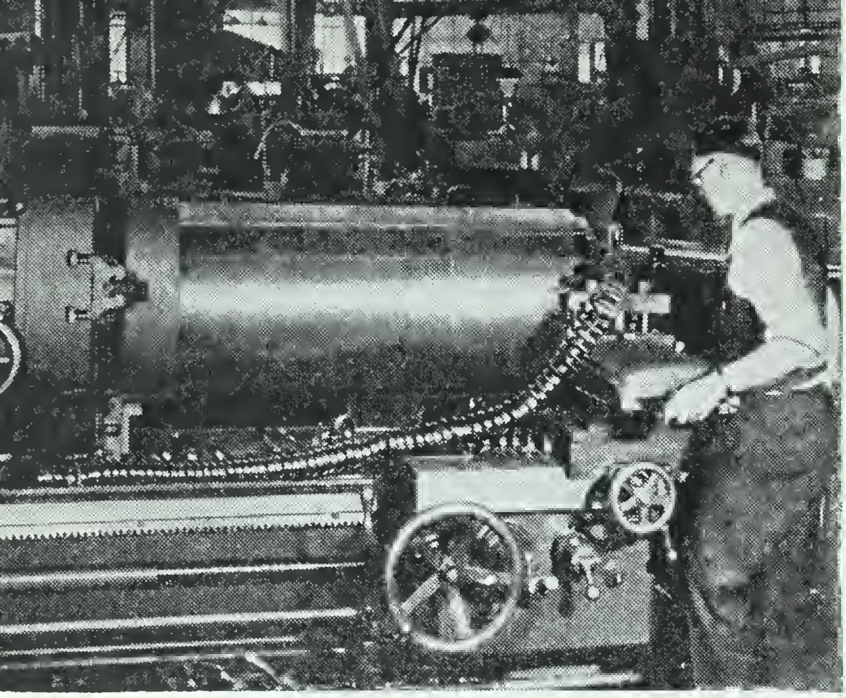
The difference between steel and iron is based upon such technical and small points that there is no one way of distinguishing the two metals. Steel is formed by treatment of iron—either by adding or removing carbon, by putting into the iron other metals, or by special methods of treating the iron with heat.

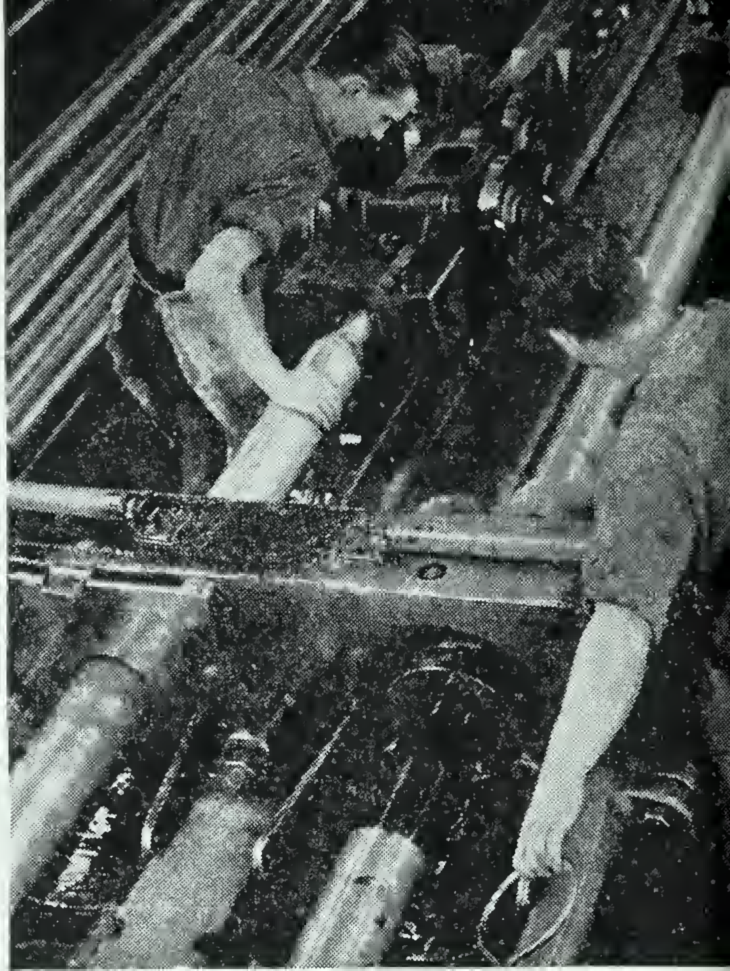
How are metals worked? The properties of metals make them absolutely indispensable in manufacturing, building, transportation, and other industries. Metals are worked in several ways.

Melted metals may be poured into molds shaped to form the desired articles. Parts of engines, stoves, large machines and some tools are made by this process, which is called casting. Cast iron is brittle and rather easily broken. Cast steel may be quite strong.

Iron which can be hammered—the type used in making horseshoes—is called wrought iron. Wrought iron and steel may be heated until it is soft, and stamped or pressed by machines into various shapes. Parts of automobiles and many tools are made by this process, which is called forging.

Metal may be rolled or drawn into thin sheets or tubes. So-called "tin" cans, kettles, metal houses, culverts, tank





Courtesy the American Tool Works Company and The Aluminum Company of America

Metal is easily cut or drawn into wires or tubes. In the above picture, a cylinder of metal is rotated by a lathe. A cutting tool cuts from it a long spiral shaving. The picture to the right shows a step in the process of drawing aluminum into tubing.

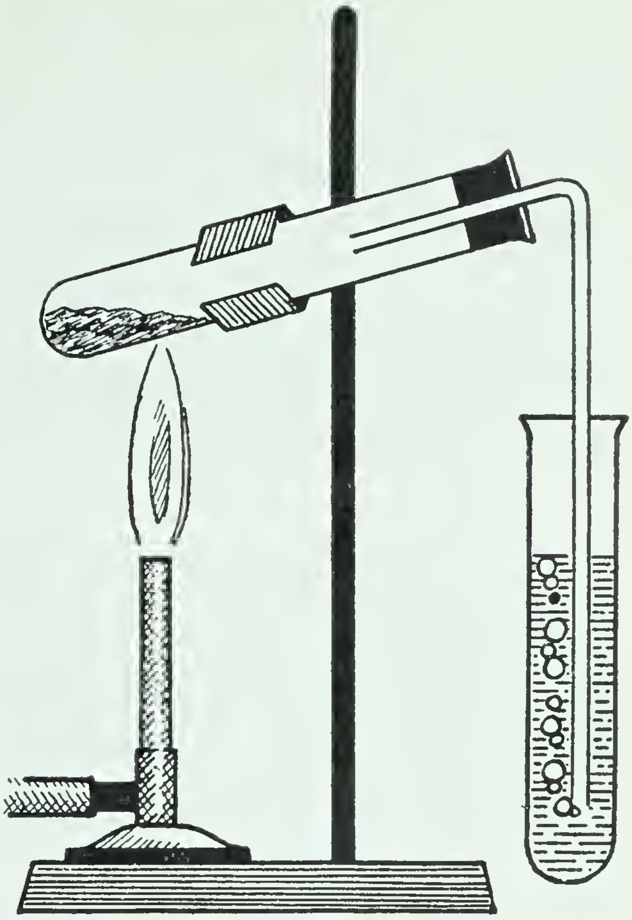
cars, and stovepipe are some of the common articles made from sheet steel. The sheet steel is made by forcing a huge bar of iron between rollers. Each set of rollers presses the sheet thinner than it was before, until it reaches the desired thickness. Metal may be rolled either hot or cold. Metal may also be drawn through holes to form wires and pipes.

Although it is tough and hard, metal may be cut, ground, or polished. The metal lathe turns a piece of metal so that when a sharp tool is held against the turning metal a shaving is cut from it. Almost perfect roundness may be obtained by using the lathe. Drills are used to bore holes in metal. The insides of automobile cylinders are ground with an abrasive (grinding powder or stone). Most metals may be cut with a hack saw.

Metal may also be cut with an oxyacetylene [ŏk′sĭ·ȧ·sĕt′ĭ·lēn, fuel gas] torch. This torch actually produces a flame hot enough to melt and burn through an inch-thick steel bar in a few seconds. Metals can be joined together by melting. Sometimes heating and hammering are sufficient to join pieces of metal. Blacksmiths may weld a new point on a

plowshare, or they may weld a broken automobile bumper. Welding is joining pieces of metal by melting them together.

Of what use are alloys? There are many needs for which there is no natural metal that exactly serves. To meet these needs, various mixtures of metals called alloys have been developed.



This diagram shows how you should arrange the apparatus for the next demonstration.

One of the oldest and commonest of the alloys is solder [sŏd′ẽr]. Before more modern methods were developed, solder was used extensively to join together metals with high melting points. Solder is a mixture of lead and tin in various proportions, and melts at temperatures of around 350 to 400 degrees Fahrenheit. To solder two pieces of metal, the surfaces to be joined are cleaned with acid or by polishing. Then a hot soldering iron or copper is pressed against the metal surfaces to heat them, the hot iron touched with the solder, and the drop which forms is used to join the pieces of metal. Pots and pans and water pipes must never be soldered. Use of solder in contact with foods is dangerous, for lead is poison.

Steel alloys are used widely. When combined with the rare metals—tungsten, chromium, vanadium, cobalt, manganese, or molybdenum—steel becomes harder and tougher. Cutting tools, magnets, armor plate, ball bearings, and strong machines are made of these steel alloys.

The wire used in electric heating coils is nichrome, which is an alloy of iron, chromium, and nickel. This wire resists burning and has a high resistance to electricity. The five-cent coin is an alloy of copper and nickel or silver. The white color is caused by the small amount of nickel. Alloys are

used to harden gold and silver. Nickel in gold makes it white. Older alloys are bronze, brass, and pewter. Pewter, being a lead alloy, is dangerous to use for containers of foods.

An interesting alloy is used in the automatic fire sprinklers used inside stores, factories, and other buildings. A plug is held in an opening of a pipe by a piece of metal which melts readily. When the building begins to burn, the heat melts the metal, and the plug is forced from the pipe. The flow of water is then started from the sprinkler.

Demonstration. How Are Ores Purified?

What to use: Copper oxide or lead oxide, charcoal, hard glass test tube, ring stand and clamp, burner, stopper, delivery tube, test tube, limewater, mercuric oxide, splint.

What to do: Set up the apparatus as shown in the diagram on page 165. Heat the mixture of copper oxide and charcoal for several minutes in a hot flame. Test the gas as shown. When the tube cools, pour the contents into a large test tube of water, and shake vigorously. Pour off the liquid and floating solids. Examine the sediment.

Heat mercuric oxide in the hard glass test tube. Test the gas given off with a glowing splint.

What was observed: Describe all changes which occurred in each experiment.

What was learned: What are two ways of separating metals from their ores?

Filmstrip: Iron and steel. S.V.E.

Exercise. *Complete the following sentences:* Into the blast furnace are put —1— and —2— which react chemically to produce —3— and —4—. —5— is put into the blast furnace to form slag. Many ores are —6— to separate the metal from sulphur or carbon dioxide. Steel is made from the element —7—. Metals may be worked because they soften when —8—, and can be drawn into —9— or rolled into —10—. A mixture of metals is an —11—.

Science activity. Make a model bellows and forge. Use a flower pot for the fuel container. Study pictures to find out how to construct and operate your model.

A Review of the Unit

When man learned to control matter and energy, civilization became possible. Every change in position, chemical make-up, state, or other property of matter is accompanied by and dependent upon a change in the amount of energy present.

Matter and energy seem to be different forms of the same thing. Matter is changed physically when the molecules remain unchanged; it is changed chemically when atoms rearrange themselves in molecules.

Some common physical changes are expansion, change of state, solution, suspension, warming and cooling, and change of position. Some common chemical changes are burning, reaction of acids with bases or metals to form salts, purification of metals, refining of petroleum, and making of oxygen.

No matter what change may take place, energy cannot be created or destroyed. Matter may change form or change to energy, but it is not destroyed.

An exercise in thinking

Match the principles and related ideas, according to the directions given in the review at the end of Unit I.

List of principles

A. Matter or energy cannot be destroyed by chemical means.

B. For every change in matter, there is a change in the amount of energy present.

C. In a physical change the atoms within the molecule remain unchanged.

D. A chemical change produces a new arrangement or combination of atoms within the molecule.

E. Gravitation is the attraction of every object in the universe for every other object.

F. Radiant energy travels in waves which move in straight lines through space.

G. Convection is the transfer of energy by currents in liquids or gases.

H. Conduction is the transfer of energy from one molecule or object to another.

I. A solution consists of molecules of a solid, liquid, or gas occupying space between the molecules of a liquid.

J. A gas exerts pressure upon a surface because of the force of the molecules striking the surface.

List of related ideas

1. The source of most of the heat on the earth is the sun.
2. Steel is made by adding materials to the element iron.
3. Molecules of matter are in continuous motion.
4. If a piece of coal is burned in a sealed jar, the weight of the jar and contents is the same after burning as before.
5. Water freezes at 0 degrees centigrade.
6. Iron rusts in air by combining with oxygen.
7. When a substance reaches its kindling temperature, it burns.
8. A B.T.U. is the amount of heat needed to raise one pound of water to one degree Fahrenheit.
9. Grinding beef produces hamburger.
10. When water vapor condenses, heat is given off.
11. Iron ore plus coke yields iron plus carbon dioxide.
12. Soda pop contains carbon dioxide.
13. A wire hot at one end soon becomes hot at the other end.
14. Air circulates in a room.
15. Water boils at lower temperatures on high mountains.
16. Red mercury rust gives off oxygen when heated.
17. Mercury in a thermometer expands when heated.
18. Air pressure is 14.7 pounds per square inch.
19. Acids turn litmus paper red.
20. Potassium chlorate gives off oxygen when heated.
21. Water vapor is the lightest gas in the air.
22. The side toward an open fire feels warmer.
23. The temperature of the ocean depths remains about 40 degrees.
24. A good reflector is a poor radiator.
25. When atoms combine they form molecules.
26. The weight of matter produced by burning equals the total weight of the oxygen and fuel.
27. Automobile tires are hard.
28. Infrared rays travel from a hot iron but are invisible.
29. Oil, eggs, and seasoning beaten together make mayonnaise.
30. Electricity travels along wires.
31. Bubbles of oxygen may be driven from water by heating it.
32. The total mass of the universe does not change, no matter what changes may take place in its parts.
33. A falling body always moves toward the center of the earth.
34. We obtain most of our controlled energy by burning coal.
35. Oil shoots from the well when a gusher comes in.

36. Sulphuric acid is used in automobile batteries to produce current.

37. A vacuum does not conduct heat.

38. A kerosene lamp flame gets its color from the heated carbon in it.

39. Objects weigh more on the earth than on the moon.

40. Acids react with metals to form salts.

Some things to explain

1. What is the most important reason for knowing about chemical changes?

2. Discuss this statement: The average woman uses more applied science in the home than the average man does at his work.

3. If the sun should instantly become cold, would we know it at the same instant?

4. Does it seem possible that the shortest radio waves might produce a slight amount of heat?

5. Explain how your energy used in running comes from the sun.

6. Why do we say that we live in the age of metals?

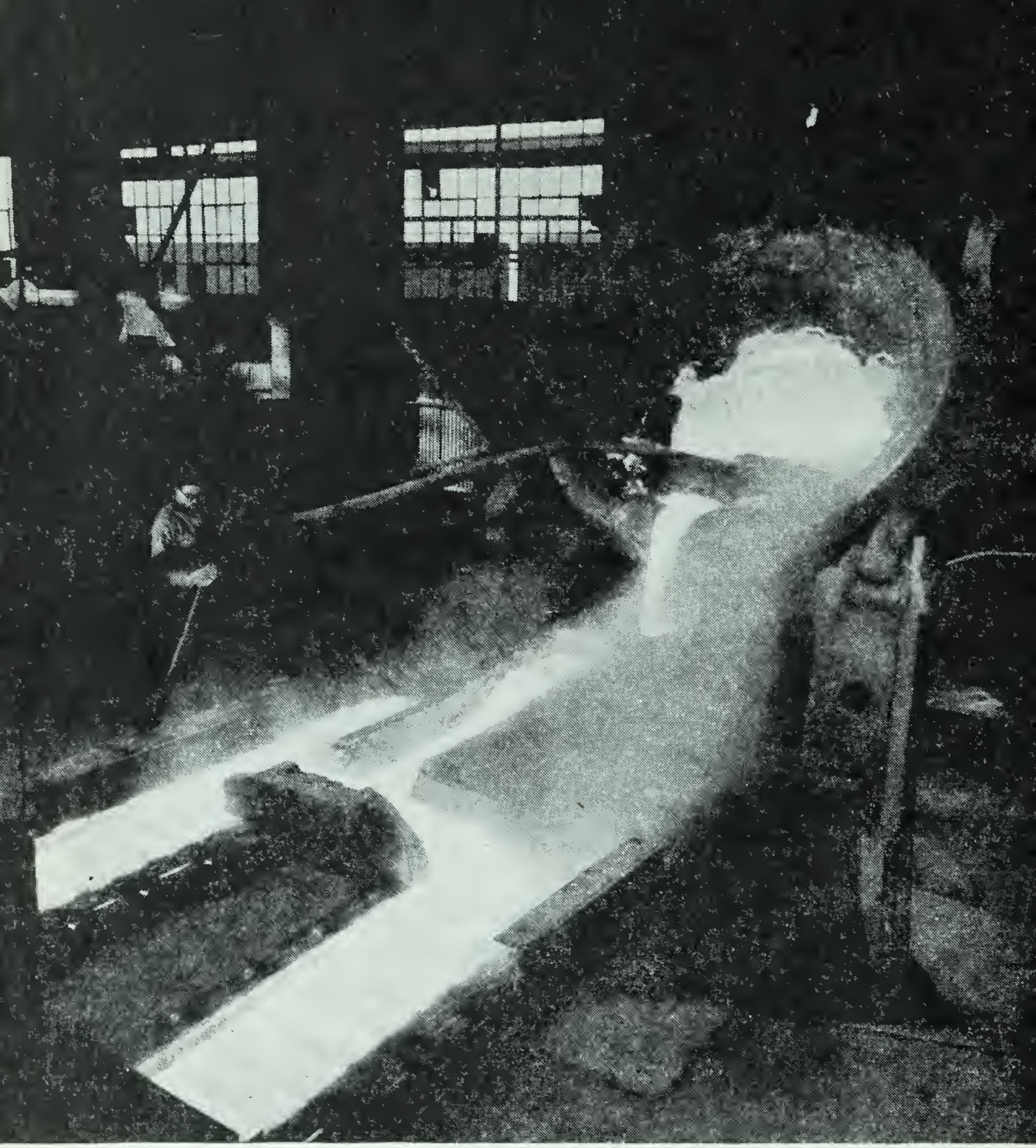
7. Do you think that we can soon say that we live in an age of synthetic chemicals? Why?

8. What is the difference between temperature and heat?

9. Why is coal the most important source of energy under our control?

Some good books to read

The Book of Knowledge
Book of Popular Science, Grolier Society
Bragg, H. H., *Concerning the Nature of Things*
Chamberlain, J. S. and Browne, C. A., *Chemistry in Agriculture*
Compton's Pictured Encyclopedia
Gibson, C. R., *Chemistry and Its Mysteries*
Harrow, B., *The Making of Chemistry*
Howe, H. E. and Turner, F. M., *Chemistry in the Home*
Jaffee, Bernard, *New World of Chemistry*
Kruh, Frank O., Carleton, Robert H., and Carpenter, Floyd F., *Modern-Life Chemistry*
Williams, H. S., *The Story of Modern Science*
World Book Encyclopedia



Courtesy International Harvester Company

The melted iron is poured from the ladle into sand molds to form pigs. When the pigs are cooled they are either stored or remelted for further purification.

Some interesting motion pictures

Energy and Its Transformation. Erpi (*16 sound*)

Historical Introduction to the Study of Chemistry. Eastman (*16 silent*)

Molecular Theory of Matter. Erpi (*16 sound*)

Atmospheric Pressure. Eastman (*16 silent*)

Wonder World of Chemistry. Y.M.C.A. Motion Picture Bureau (*16 sound*)

Oxidation and Reduction. Erpi (*16 sound*)

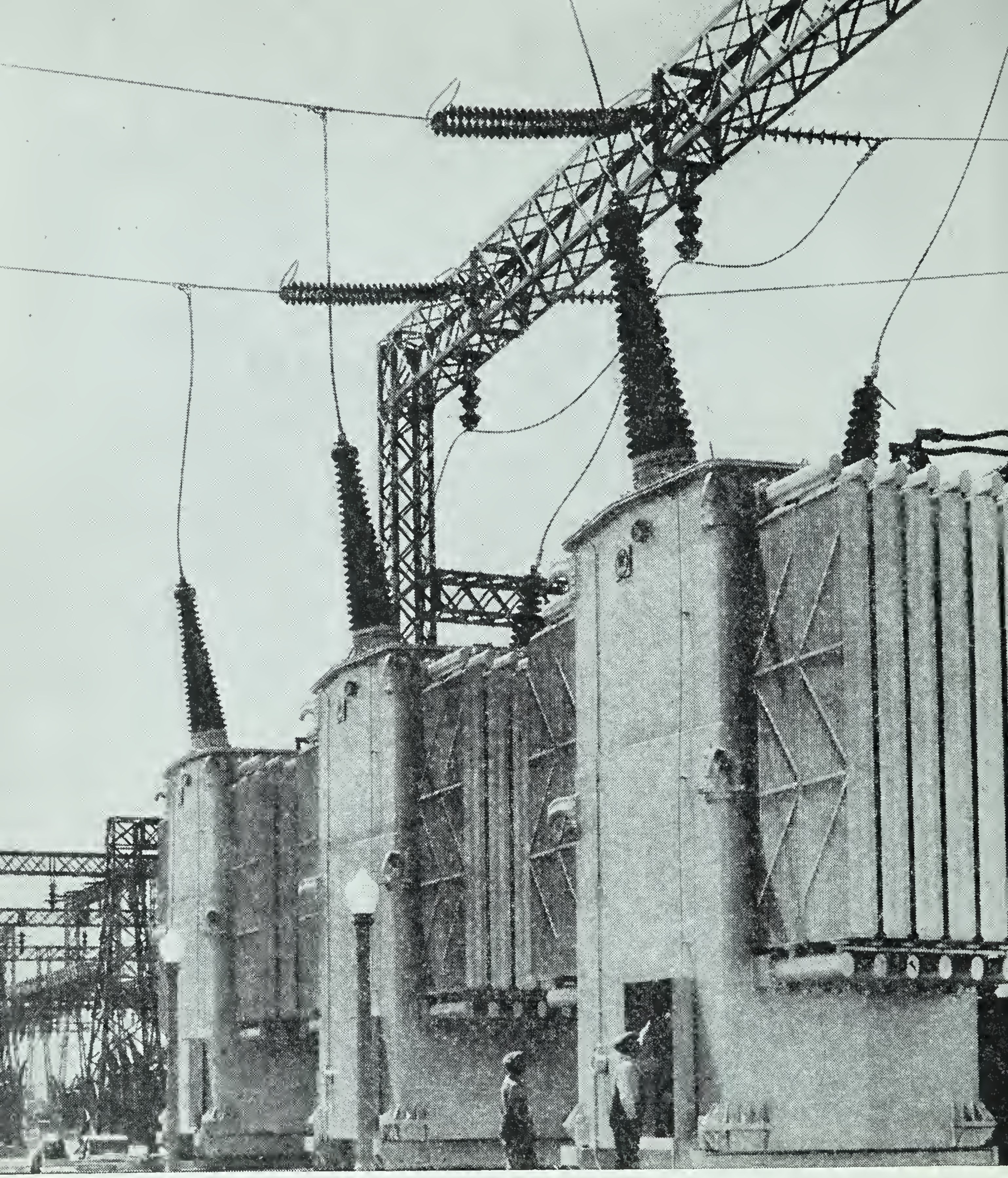
Experiments in Conduction of Heat. Bray (*16 silent*)

Science Saves the Surface. Y.M.C.A. Motion Picture Bureau (*16 sound*)

Nature's Chemistry. Y.M.C.A. Motion Picture Bureau (*16 sound*)

Chemistry of Combustion. Edited Pictures (*16 silent*)

Atmospheric Gradation. Erpi (*16 sound*)



UNIT FOUR

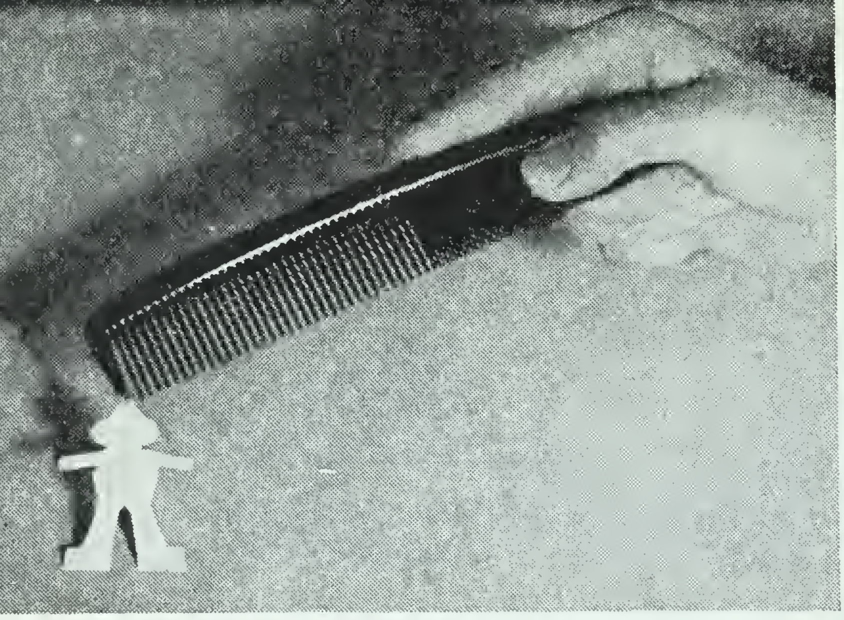
HOW DO WE USE ELECTRICITY?

NO OTHER force has determined more completely our modern way of living than has the force of electricity. We may think first of our electric lights, our radios, and our streetcars as being the most common means of using electricity. But then, too, we have the labor-saving devices in the home—the vacuum cleaner, the sewing machine, the washing machine, the toaster, the iron, and the many other devices which make the work of women pleasant and easy compared with the work in homes 50 years ago. It has been said that men produce the electricity but that women use it. The woman working in a modern home has more contact with electrical devices than do many men. Because of the widespread use of electricity, girls of today are able to look forward to a life of comparative freedom from the drudgery of housework.

Boys find electricity a fascinating field of study, both for the purpose of finding a lifetime occupation and for the fun of developing hobbies connected with electricity.

There is scarcely an occupation or industry in which some knowledge of electricity is not required. Beauty-parlor operators, bookkeepers, nurses, cooks, dentists, poultrymen, and those engaged in many other types of work constantly use electricity in their work. It is almost impossible to find any activity in which some type of electrical device does not play a part. Electricity is even used to shock angleworms to make them come to the surface where they can be picked up and used for bait for fishing!

There are so many changes produced daily in the world with the help of electricity that we cannot imagine getting along without it. Only 50 years or more ago people read by light of kerosene lamps and used irons heated on the stove. They washed by hand in a wooden tub on a washboard, fanned themselves with palm leaves, and wrote long letters by hand instead of telephoning. Women cooked on a wood or coal range, and waved their hair by heating a curling iron in a kerosene lamp. Today we use electricity for these operations and for many more. It might be interesting to continue this list of differences in old and new ways of living. Can you add 20 more important modern operations to the list?



If you charge a rubber comb by running it quickly through your dry hair, it will pick up bits of paper. Why does lint stick to a photographic film that has been brushed against wool?

1. What is electricity?

Electricity is a form of energy. It can be used to do work, to heat wires and coils, to bring about chemical changes, and to give off light. Although no one knows what electricity is, we know enough about it to describe its behavior, to produce and use it, to measure it, and to weigh electrical charges.

What is static electricity? About 2500 years ago someone discovered that if amber (a yellowish, fossilized resin found along the seacoast of many countries) was rubbed with silk, the amber would attract to itself small bits of paper or plant pith. From this experiment the word "electricity" was derived, for the Greek word for amber was *elektron*. The electricity produced by this experiment today is called static [stăt′ĭk, to stand still] electricity, because it is stored in a nonconducting material. Current electricity flows through conducting materials.

A rubber comb run briskly through the hair produces static electricity. The comb is charged because the rubbing dislodges electrons, and the electrical balance is upset. When an object has too many or too few electrons, it is charged. Electrons are charges of negative electricity.

If you hang two balls of dry plant pith from silk threads and charge them by touching them with a charged comb, they repel each other. If, after they are charged, you hold near them a glass rod which has been rubbed with silk, they swing immediately toward the glass and cling to it.

What is the law of electrical charges? The comb has a negative charge. When the two pith balls are charged with negative electricity, they repel each other. The first part of the law is: *Like charges repel each other.*

The glass rod is charged with positive electricity. The pith balls are attracted to the glass rod. To the law is added:

Unlike charges attract each other. If the two pith balls are charged fully by touching them with a charged glass rod, they will again repel each other, and will be attracted by a charged comb.

Where does static occur? Where the air is dry, you can produce an electric spark by first sliding your feet along the rug and then touching a piece of metal, such as a drinking fountain or lamp. When you charge your hair by combing it, it may stand up, for the electrically charged hairs repel each other. Sparks can sometimes be seen when a cat's fur is stroked in the dark.

From leather belts used to operate machines, sparks of static electricity may leap for a distance of several inches. Such sparks are quite painful if they strike the skin. They may also cause explosions if there is an explosive mixture of air and fuel gas or of air and vapor of alcohol, gasoline, or kerosene present.

The upper air is charged by energy resulting from magnetic storms on the sun. Cosmic rays and other forms of radiation cause the upper air to become charged. Probably no electrons reach the earth from the sun, but the electromagnetic radiations can set electrons free in the atmosphere. Such disturbances sometimes become powerful enough to disturb telephone, telegraph, and radio communication.

The most exciting display of static is lightning. The friction of the air causes raindrops to become charged, and the charged raindrops break up into smaller drops, separating the balanced electrical charges into unbalanced charges. When there is a sufficient charge—one equal to billions of volts—a spark leaps from one cloud to another or from the cloud to the ground. The spark forces the air apart, and then the air rushes back into the partial vacuum created by the spark. The resulting noise is thunder.

What is current electricity? To be exact, one must refer to the discharge of static electricity as a current. For when the electrons move, a current is produced.

A more usual way of producing a current is to connect two charged bodies by a wire, and the electrons then flow along the wire instead of leaping through the air to form a spark.

A current flows only when there is a difference in the electrical pressure between two points. This electrical pressure is called voltage. There are four practical ways of generating voltages to produce currents. Wires or coils may be moved through a magnetic field. Chemical action in cells generates a voltage. In the photoelectric cell voltage is generated when light rays strike the active materials of the cell. When two different metals are joined, voltage may be generated by heating them at the point where they join.

Most of our light and power current is produced by the use of coils and magnets in machines called dynamos. Dynamos may make either of two kinds of current: direct or alternating. In a direct current, the electrons always move in one direction. They may move steadily or in surges, but they always move in the same direction. In an alternating current, the electrons move alternately in one direction and then in the other. These two kinds of current are abbreviated D.C. and A.C. The light current is usually alternating and makes 60 complete changes per second. These complete changes are called cycles.

The electric cell is a source of a direct current, such as is used for flashlights.

The photoelectric cell consists of a metal or compound, which gives off electrons when light shines upon it, and conductors for carrying the current produced when freed electrons move away from the source. It is used for measuring light for photography and for testing strength of illumination. Television, talking pictures, and wired photographs also depend upon the photoelectric cell.

The thermocouple is made of two kinds of metal in close contact with each other. When the coupled metals are heated, a small voltage is generated and measured by a sensitive meter. It is used for measuring temperatures in furnaces which would melt or break ordinary thermometers. The current is caused by electrons passing from one metal to the other.

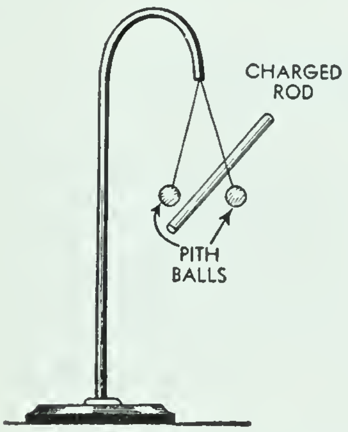
Electric currents are much commoner than most people suppose. In your nerve cells tiny currents flow. Each cell in living organisms seems to have a positive and a negative end. Electricity seems to be one of the chief forces of life.

An electric eel found in South American waters gives so strong a shock that it will disable a man.

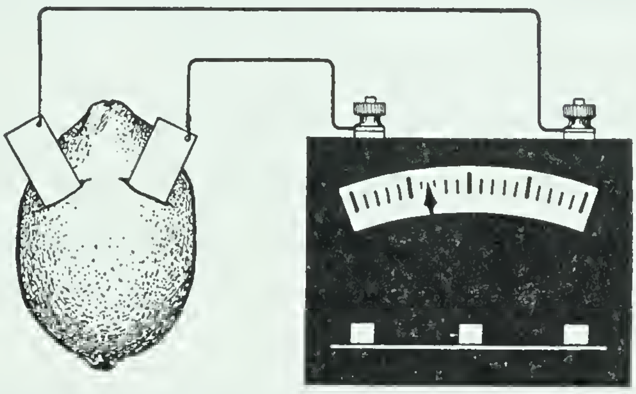
Currents set up in the ground corrode the metals of water and gas pipes. When one's mouth contains gold and silver fillings, a small current is produced in the mouth. A current is produced in any solution containing an acid, base, or salt and two unlike metals.

Demonstration. What Is Electricity?

What to use: Glass rod, silk, hard rubber or ebony rod or comb, wool or fur, pith balls suspended from thread, lemon, copper and zinc strips, wire, nail, compass.



A charged rod may be used to charge the pith balls. When all three have been charged similarly, they repel each other.



By thrusting strips of zinc and copper into a lemon, a cell can be made capable of producing a small current. The current is produced by chemical action.

What to do: Suspend the pith balls as shown in the diagram. Charge the ebony rod by rubbing it with the fur, and charge the balls by touching them. Repel the pith balls as shown in the diagram. Repeat the experiment, using the glass rod charged by rubbing it with silk.

Cut two slits in the lemon, and insert the copper and zinc strips as shown in the diagram. Wrap a nail with insulated wire, and attach the wire to the strips. Try the magnet formed to see if it will lift a pin. Repel and attract the needle of the compass.

What was observed: Describe in detail what you observed in each part of the experiment.

What was learned: State the law of electrical charges, and give

proof as observed in the demonstration. State one way in which a current may be made, and state one effect of a current.

Exercise. *Complete the following sentences:* Electricity is a form of —1—. Negative electrical charges are called —2—. Static electricity accumulates in —3—. Lightning is —4— electricity accumulated in —5—. An electric current is a flow of —6— along a —7—. Five ways of producing a voltage are by —8— and coils, by connecting charged —9—, by —10— changes, by use of the —11— cell, and by heating joined —12—.

Science activity. Cut figures of dolls from tissue paper, and weight their feet by pasting bits of cardboard to them. Put them in a cigar box, and cover the box with celluloid. Rub the celluloid with wool cloth, and the figures will stand up. Why?

2. How is electricity related to magnetism?

More than 2000 years ago it was discovered that a certain iron ore, magnetite, had the power of attracting pieces of iron. When a small piece of this ore or magnetized iron was used for a magnet, it was called a lodestone (leading stone) because it points in the general direction of the North, or lode, Star.

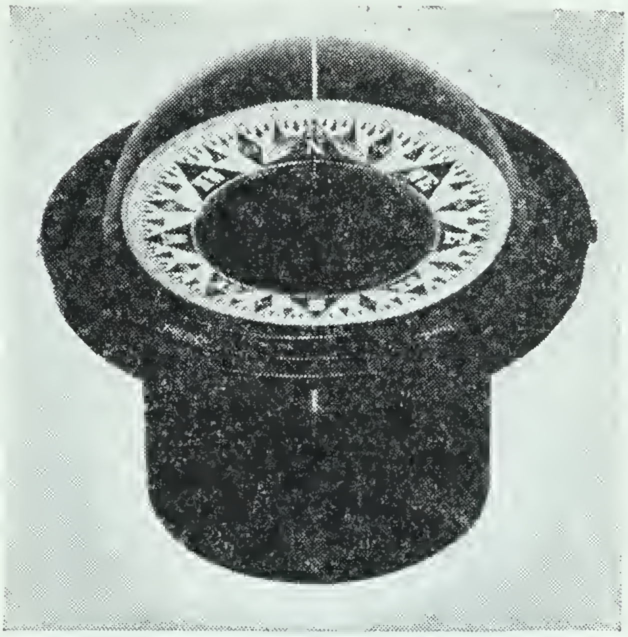
What is a compass? The compass is a magnetized needle mounted on a pivot so that it turns easily. The earth is a magnet, with one of its magnetic poles located in northern Canada near Hudson Bay. Because unlike magnetic poles attract each other, the compass needle points toward the north magnetic pole. The compass points to true north at Cincinnati, Ohio, about 20 degrees northwest in Maine, and about 20 degrees northeast in the state of Washington. Allowance must be made for the difference between magnetic north and true north when one uses a compass.

The compass as used in navigation is made up of a needle attached to a cardboard disk on which the directions are marked. The card is mounted on a pivot, and may turn freely. Some compasses are mounted in liquid, and some on pairs of rings so arranged that no matter which way the ship rolls, the compass remains level.

How are permanent magnets made? Permanent magnets are bars or rods of hard steel. The bars may be straight or

bent into a horseshoe, or U, shape. The best permanent magnets are alloys of iron and cobalt or nickel or both. Most permanent magnets are weak, but the strongest magnets will hold up more than 60 times their own weight.

A bar may be magnetized by putting it in a coil carrying a current and pounding it, or by rubbing it against another magnet. The molecules of the metal, which are normally scattered and irregular in arrangement, seem to turn with all their magnetic charges lined up in one direction. The sound of molecules turning in a bar as the bar was magnetized has been broadcast over the radio.



Courtesy Kelvin and Wilfred O. White Company

The mariner's compass depends upon a magnet to turn the card. The many points on the compass make it possible to determine direction with a fair degree of accuracy.

A permanent magnet is part of the telephone receiver. Tack hammers and scissors are often magnetized.

What is a magnetic field? Magnetism is a force. That is, magnetism may push or pull upon matter. The unit of magnetic force is called a "line of force." These lines of force are more abundant and closer together around strong than around weak magnets. If two bar magnets are laid on a table and covered with glass, iron filings sprinkled upon the glass arrange themselves in closed curves along the lines of force. The total number of lines of force is called the magnetic field.

Any wire or other conductor carrying a current is surrounded by magnetic lines of force. These lines of force cease to exist when the current is shut off, for they return to the magnet. Insulation of the wire does not insulate against the magnetic lines of force.

What is the law of magnets? If you bring a magnet near a compass, the compass is more affected by the magnet than by the earth's magnetism. The north end of the compass is

Courtesy The International Nickel Co., Inc.

A one-pound permanent magnet supports the weight of a 60-pound cabinet. The magnet is made of an alloy of nickel, aluminum, and cobalt.

attracted by the south end of the magnet and repelled by the north end. The letters N and S on magnets mean north-seeking and south-seeking. The law of magnets is: *Like poles repel; unlike poles attract.*

How are electromagnets used? As you know, an electromagnet is made up of a coil of insulated wire surrounding a rod or bundle of rods of soft iron. The iron core concentrates the magnetic fields of the turns of wire in the coil. The core is similar to a permanent magnet when the current is flowing. When the current stops, the core loses most of its magnetism immediately, and all of it eventually.

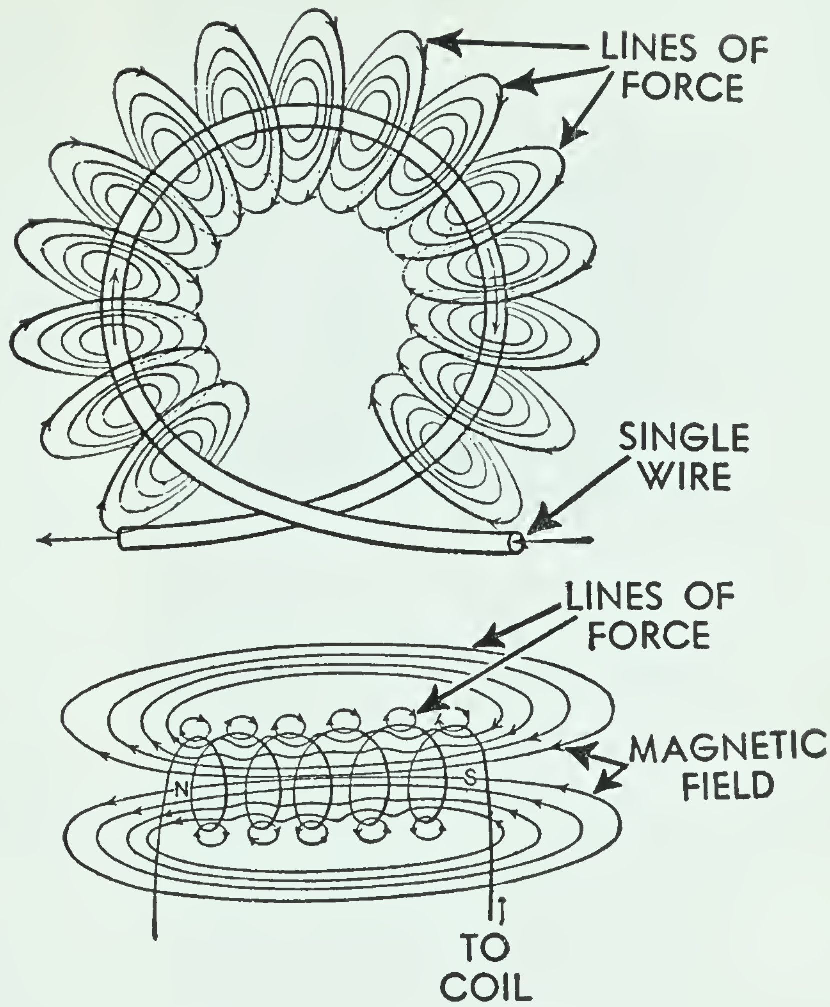
The magnetic effect of a current is one of the two most useful types of energy derived from electricity. Electromagnets form essential parts of every telephone, telegraph, radio, transformer, motor, generator, doorbell, electric razor, electric clock, and coil used in electrical machines.

Electromagnets are further used in industry in handling pig iron, waste iron, and iron and steel rods and bars. Electromagnets are used to pick up waste iron, tacks, and nails from highways, preventing unnecessary wear on automobile tires.

An electromagnet has four advantages over a permanent magnet. It can be made much stronger. Its strength may be changed by changing the strength of the current flowing

through its coils. It can be controlled by opening or closing a switch. Its poles can be reversed; that is, a north pole may be changed to a south pole and a south pole to a north, by changing the direction of flow of current through its coils.

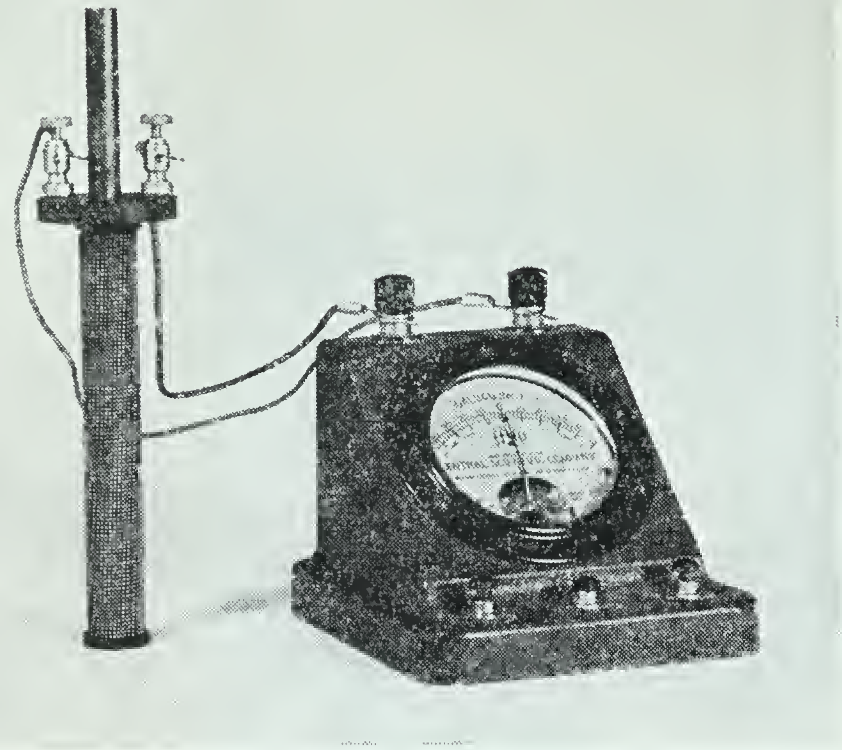
How are currents made from magnets? A voltage is generated when a magnetic field moves through a conductor, such as a coil of copper wire. The coil may move through the magnetic field or the field may move through the coil. A current produced in this way is said to be *induced.* The instant the movement of the coil or magnetic field stops, the current stops. A current flows as the result of a voltage being set up if conditions are right.



Every wire carrying a current is surrounded by magnetic lines of force which together make up a magnetic field. The wire may be wound into a coil to combine the effects of the lines of force. Note that lines of force are closed curves.

A weak current, too weak to measure except with a sensitive meter, may be produced in the laboratory with a simple coil and magnet. The sensitive meter is called a *galvanometer.* The galvanometer is a very sensitive compass suspended so that it is attracted or repelled by the magnetic field around a coil of fine wire.

Commercial light currents are produced by machines made of huge magnets and coils of wire many feet thick. The current produced by these machines, which are called dynamos, operates trains, electric lights, radio stations, and factory machinery.



When a magnetic field cuts a coil of wire, a voltage is generated. Does a current flow when the magnet is still?

Demonstration. How Is Electricity Related to Magnetism?

What to use: Magnets, electromagnets, coil, galvanometer, iron filings, four dry cells, wire, compass, paper, and glass.

What to do: Arrange the magnets so that one can move, and repel and attract the movable magnet with the other.

Test the law of magnets by use of a compass.

Put a piece of glass or paper over the magnets, and make patterns of the magnetic field by sprinkling iron filings upon the glass or paper.

Connect a wire to the two poles of the dry cell, and hold it in different directions over the compass.

Connect the electromagnet to the cells, and put a paper over the poles. Sprinkle iron filings upon the paper, and observe how they act. Remove the paper and filings, and put a piece of iron across the poles of the electromagnet. Test the strength of the magnet by pulling upon the iron.

Arrange the coil and galvanometer as shown in the picture. Move a magnet within the coil, measuring the current with the galvanometer.

What was observed: Describe briefly what happened in each step.

What was learned: State three laws of electricity and magnetism illustrated by these experiments.

Exercise. *Complete the following sentences:* A —1— is a natural magnet. A compass is a freely suspended —2— which indicates the direction of the —3— poles. Permanent magnets are made of —4—. Like poles —5—; unlike poles —6—. A coil carrying a —7— surrounding a core of soft iron is an —8—. When a conductor cuts a —9—, a —10— is generated which may produce a —11— under favorable conditions.

Science activity. Make an electromagnet, and devise experiments for its use. Make a magnetic field as follows: Dip a sheet of paper in hot paraffin and cool it. Put it over the magnet and scatter iron filings or finely cut steel wool on the paper. (*Take*

care not to get slivers of steel in your fingers.) When the filings are arranged to show the field, heat the paper gently. The filings will sink into the paraffin and stick.

Make a blueprint of a magnetic field. Use reference material for information.

3. How is current produced in cells?

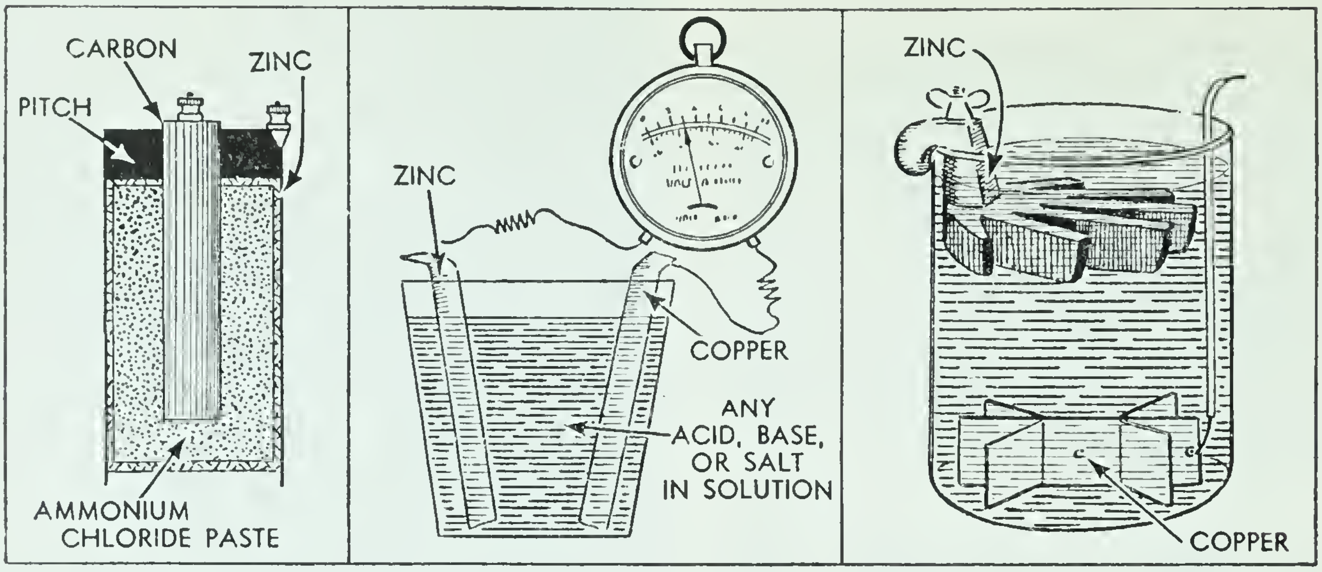
When you snap the switch of your flashlight, you probably do not think to yourself, "I am causing chemical changes to take place which produce a current which, in turn, encounters resistance, heating a wire which gives off radiant energy."

Courtesy National Carbon Company, Ltd.

Among the many uses of flashlights, an important one is in railroading. This brakeman uses his lantern for signaling, as well as for lighting his way at night.

Where does the flashlight get its energy? Dry cells are used in a flashlight to produce current. If you cut a flashlight cell, or any other dry cell, down the middle, you will find that it is a zinc can filled with chemicals surrounding a center post of carbon. You will find, too, that the so-called dry cell is not really dry but that it contains a moist paste.

The chemicals in the cell are ammonium chloride and manganese dioxide. The ammonium chloride has electrons in its molecules which become free in the moist paste. The flow of electrons along a wire from the zinc to the carbon is a current. The current is produced by a chemical change in the cell. The ammonium chloride reacts chemically with the zinc, and the zinc gradually becomes coated with a white



There are many ways of arranging the parts of a wet cell. The first drawing shows the construction of a so-called dry cell which contains a moist paste. The second shows a classroom cell. The third cell is of the type used for many years in telegraphy.

salt. The manganese dioxide prevents the accumulation of gases around the carbon in amounts that might stop the flow of current.

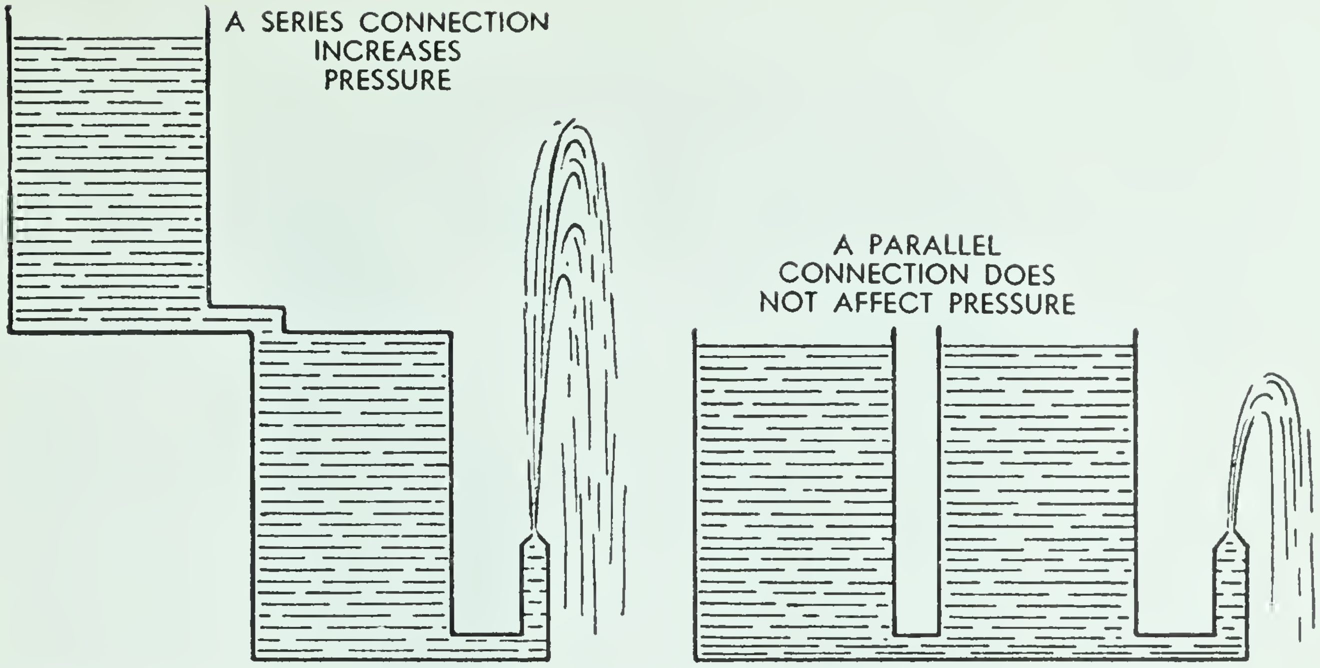
What is a wet cell? The dry cell is the product of many years of development of the wet cell. The simplest wet cell is made by putting strips of zinc and copper, or any two unlike metals, into a tumbler containing salt water. When the strips are connected with a wire, a weak current flows.

A better wet cell may be made by using copper sulphate in water or dilute sulphuric acid, instead of the salt, and by using larger strips of copper and zinc. Wet cells have been used for many years in telegraphy. Some wet cells may be operated with the switch closed without losing their strength rapidly as does a dry cell.

The wet cell was the first practical source of electricity, and was developed by the Italian scientist Volta. He made his first cell of alternate pieces of copper and zinc stacked in a pile. The pieces of metal were separated by cloth soaked in salt water.

What is a battery? When a number of cells are used together, they make up a battery. The battery of a flashlight consists of two or three cells.

If the center (positive) post of one cell is connected with the outer (negative) post of the next through a series of cells, the connection is called series.



When cells are joined in series, the voltage (pressure) is increased. When they are joined in parallel, the voltage is unchanged.

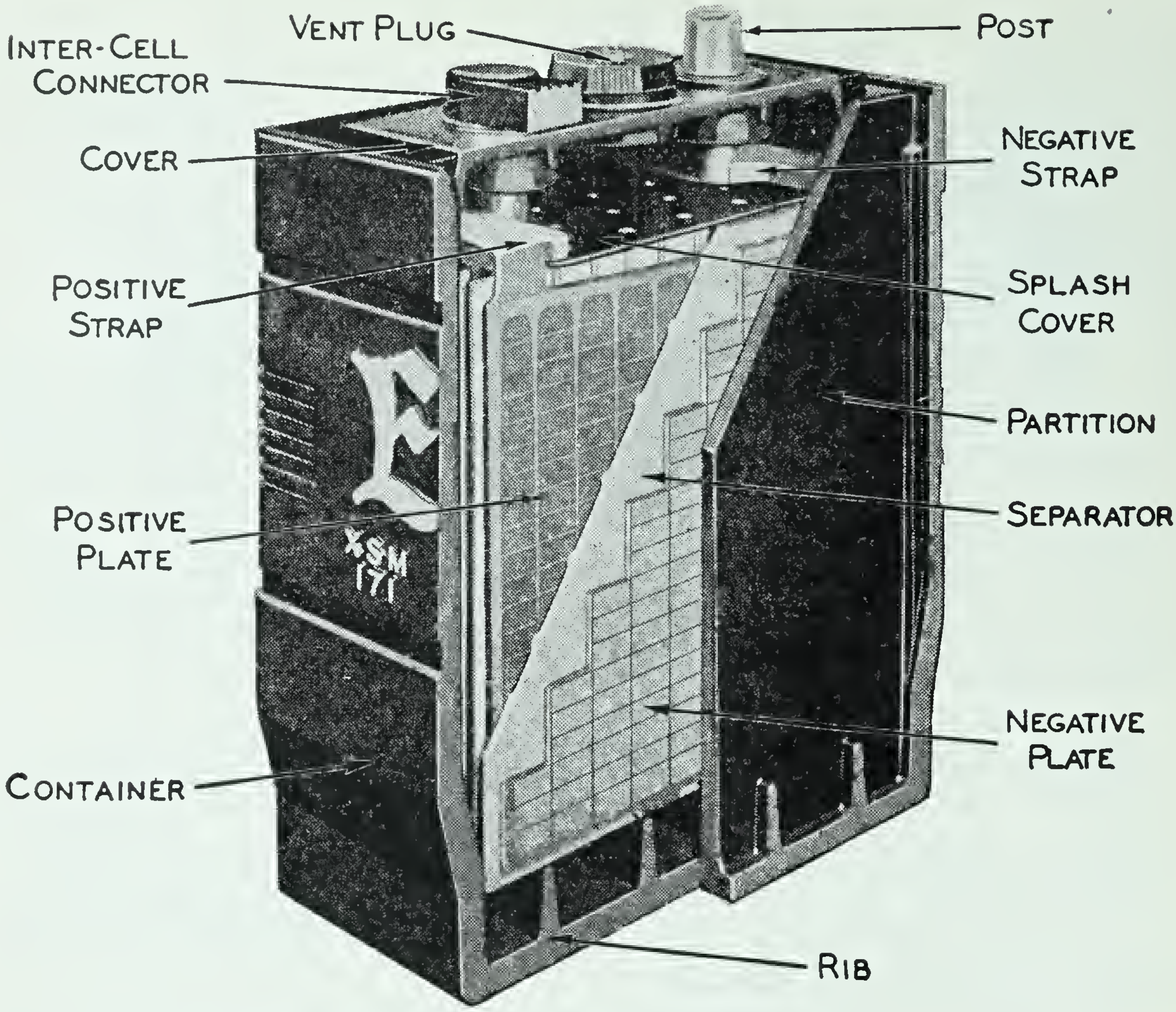
When a current flows through a wire, it encounters resistance. That which causes the current to flow is called voltage. Connecting cells in series increases the total voltage. If we connect two 1½-volt cells in series, their total voltage is 3 volts. The volt is the unit of measuring electromotive force or electrical pressure.

You may compare the series arrangement of cells with connection of water tanks as shown above. When one tank is placed on top of another, the pressure is increased in a pipe leading from the bottom of the lower tank. Electromotive force may be compared with water pressure.

If all the center posts of cells are connected to one wire and all the outer posts to another, the connection is parallel. Such a connection gives a more even flow of current over a long time. This advantage is desired in farm radios and in doorbells where batteries are troublesome to replace.

What are the uses of cells? While the dry cell is an expensive source of current, it is convenient to use. Flashlights, outboard motors, the spark of gasoline engines, doorbells, telephones, and hearing aids commonly are operated by current from dry cells. When a dry cell no longer produces a current, it must be replaced with a new one.

Three or more cells in series will produce a spark strong enough to explode gasoline vapor or escaping illuminating gas. Three-cell flashlights are not safe for use near gas.



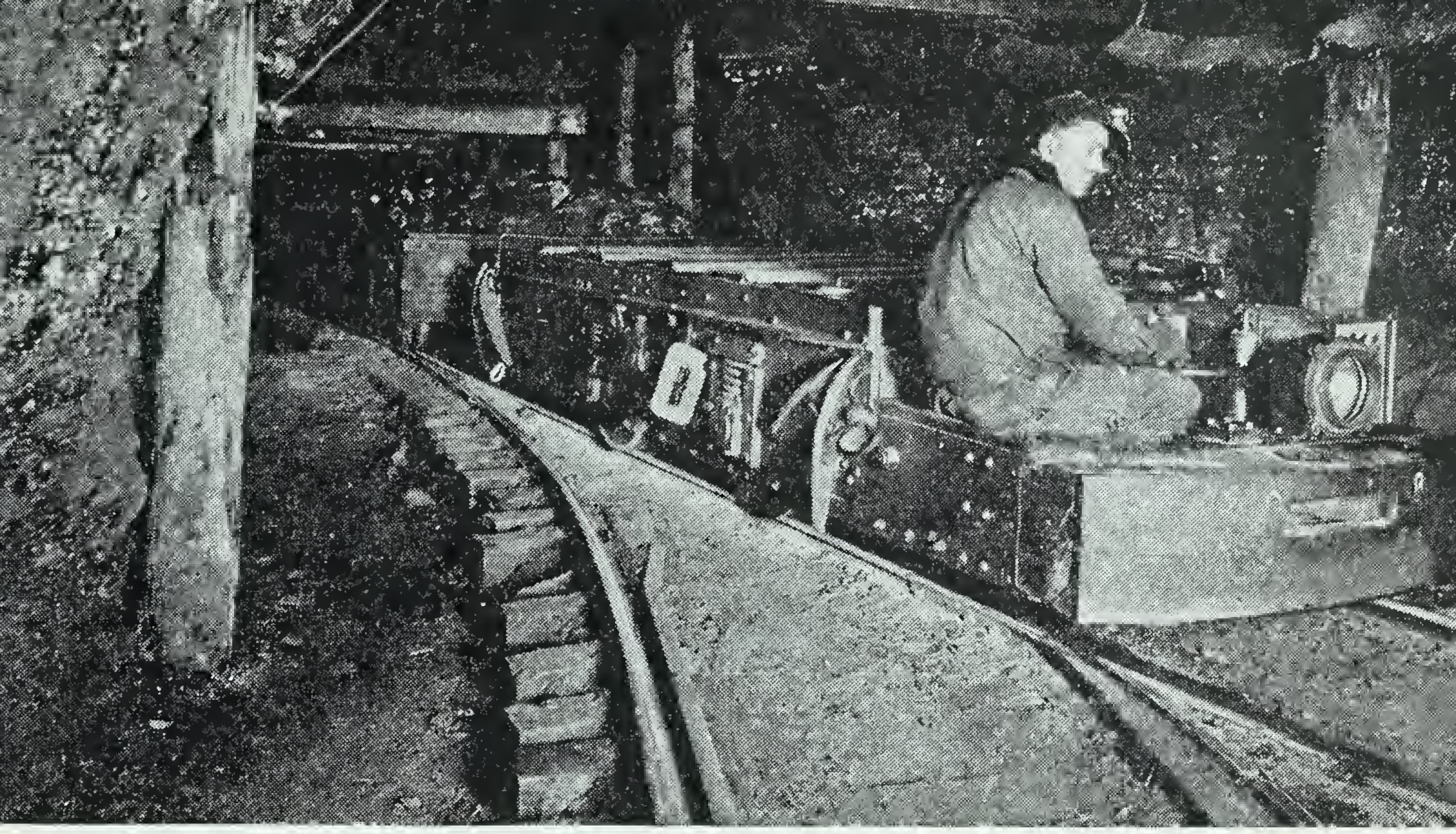
Courtesy The Electric Storage Battery Co.

Study this diagram carefully to learn the parts of a storage battery.

What is a storage cell? The simplest storage cell is made by putting two strips of lead into a sulphuric acid solution and charging them by connecting them to the posts of a series of dry cells. As the cell is charged, bubbles rise from the lead plates. One strip of lead soon becomes covered with a brown material, lead peroxide. When enough lead peroxide is accumulated on the plate, the dry cells may be removed and replaced by a doorbell. The bell will ring vigorously.

No electricity is stored in a storage cell. Instead, a current produces a chemical change to produce lead peroxide. The lead peroxide changes chemically to produce a current. It is chemical and not electrical energy which is stored. If a storage cell is recharged regularly, it may be used over and over again before its materials wear out.

A standard storage battery is contained in a hard rubber or glass box or jar. Negative plates of lead are placed in the



Courtesy The Electric Storage Battery Co.

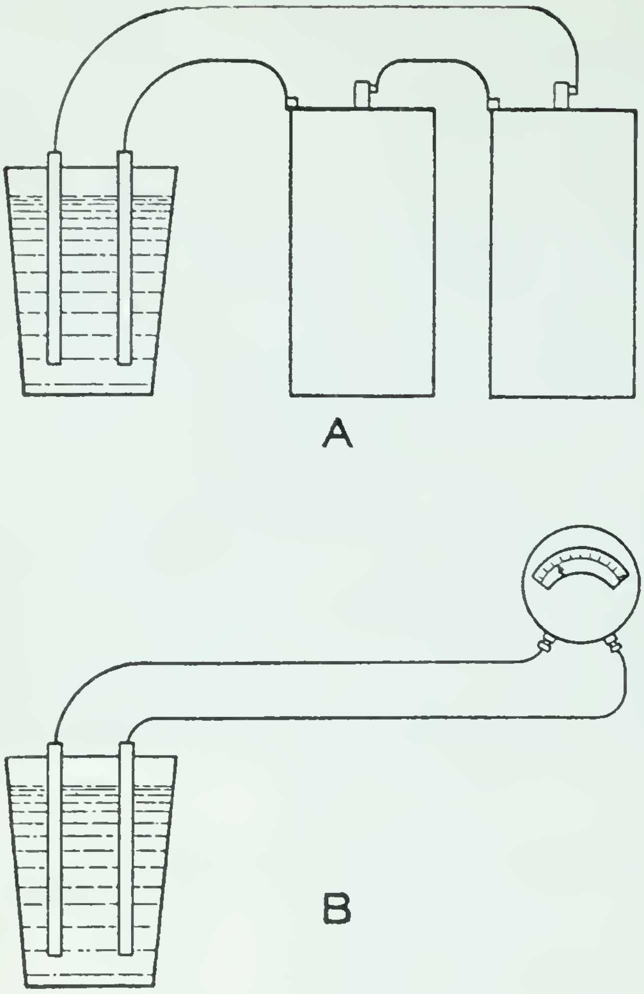
This electric locomotive used in a coal mine draws its energy from storage batteries. Such a locomotive does not give off dangerous gases and does not need a trolley.

jar—all connected to a strip of lead. Positive plates of lead peroxide are placed between the negative plates and separated from them by strips of cedar wood or porous rubber. Since there is always one more negative than positive plate, the two outer plates are negative. The negative plates are somewhat stronger than the positive plates. Each set of plates is fitted to a connection for wires. This lead storage cell produces a 2-volt current. To make a 6-volt battery, three cells are included in the battery case and connected in series.

Since a storage battery is worn out by being charged and discharged from 300 to 400 times, it is well to treat it carefully.

A battery is charged with a direct current. It must be kept properly charged or some of the lead peroxide of the positive plate will fall off. Overcharging also ruins a battery. When a battery is being charged, hydrogen and oxygen gases are given off, and sometimes they may be mixed in such a way that an explosion occurs.

When a battery is charged, the specific gravity of the acid solution increases. A fully charged battery gives a hydrom-



The charging of an experimental storage battery is shown in **A**. The amount of current from the battery may be tested as shown in **B**.

eter reading of about 1.3 or 1300, a half-charged battery a reading of 1200. The battery should be kept full by adding distilled water as needed. Charging decomposes the water.

Storage batteries are absolutely essential for operation of automobiles and farm electric-light plants. Storage batteries are used also for providing current for small trucks in factories and for delivery of materials which might absorb odors of gasoline. Some bakeries and clothing stores deliver their goods by use of electric trucks.

DEMONSTRATION. HOW DOES THE STORAGE BATTERY WORK?

What to use: Two lead strips, doorbell or battery tester, tumbler, sulphuric acid, wires, two or more dry cells.

What to do: First connect the lead plates to the tester or doorbell as shown in part B of the illustration. For a solution use 1 part of sulphuric acid poured into 10 parts of water. Be sure to pour the *acid into the water*.

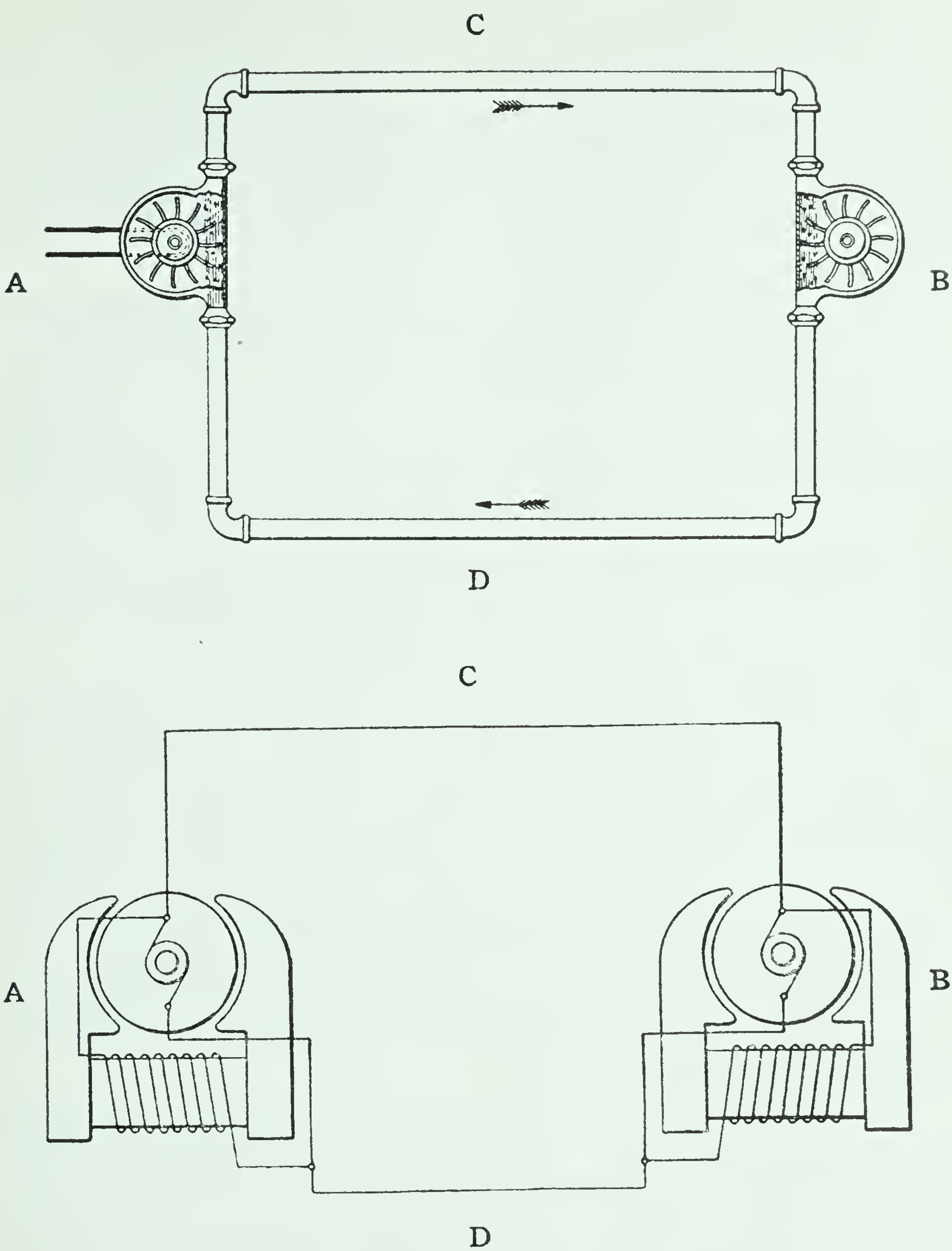
Next, connect the dry cells in series, and charge the battery as shown in part A of the diagram. When bubbles are rising freely, test them with a burning splint. The gas which explodes with a pop is hydrogen.

When one plate becomes decidedly brown, again arrange the apparatus as shown in part B of the diagram.

What was observed: Describe the results of each of the three parts of the experiment. Why was the first part performed?

What was learned: What is stored in a storage cell?

Exercise. *Complete the following sentences:* A dry cell is contained in a —1— can and has a center post of —2—. The chemical which produces the current is —3—. Wet cells may contain



In these diagrams a water system is compared to an electric system. Read the text on page 190 to understand the comparison.

almost any —4—, —5—, or —6— and two strips of unlike metals. A storage battery has plates made of —7— and —8—, and contains a solution of —9—. A storage battery stores —10— energy.

Science activity. Visit a battery charging or reconditioning plant to learn how commercial storage batteries are handled.

4. How are light and power currents produced?

More than half the homes of the United States have some form of electric lighting, every automobile has a lighting system, and all towns and cities have street lighting systems. The amount of energy needed for all the light and power systems of the country is so enormous that enough current could not be produced in cells or batteries.

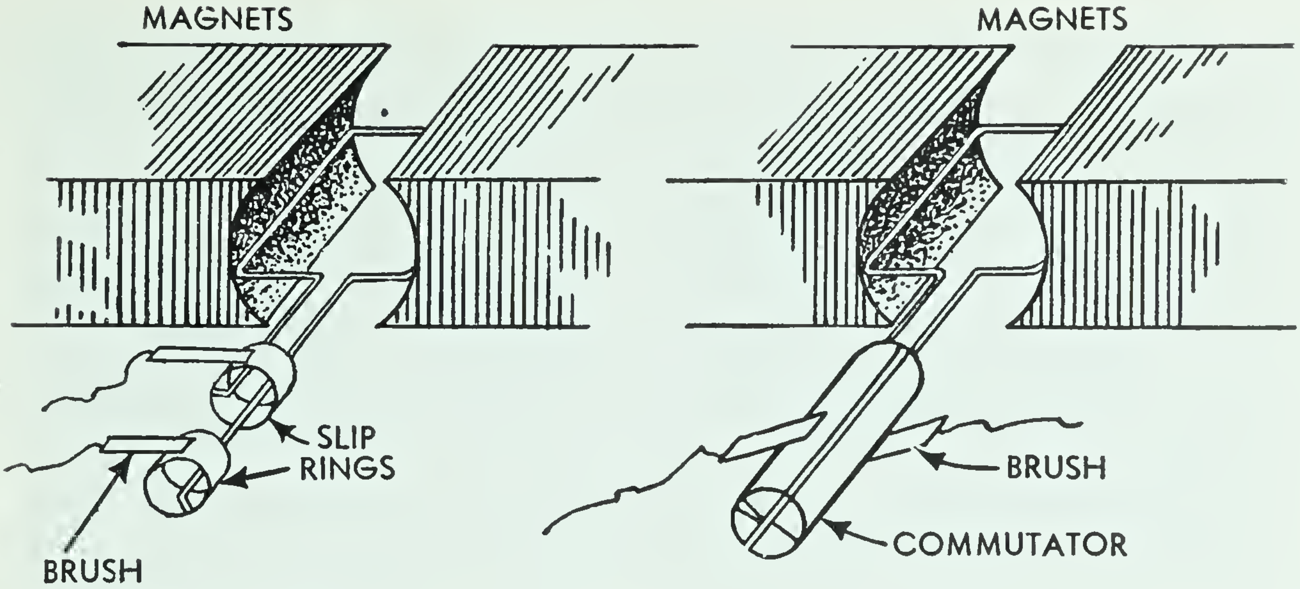
To understand how mechanical energy is transformed into electrical energy, let us first study a system which uses water instead of electricity to transfer energy. If we have a circuit or complete system of water pipes, the water can be caused to flow around the system by installing a pump as indicated by A of the top diagram on page 189. The pump is turned by some kind of engine. Now, if we wish to get the energy back, and not have it wasted in friction in the pipes, we may put in a water motor at B. The energy of the flowing water turns the motor, and work can be done.

An electrical system is in many ways similar to the water system. It is necessary to have a circuit or closed system through which the current flows. It is necessary to have some force to move or "pump" electrons through the system. And unless we put into the circuit some useful machines, the energy of the electric current is changed to heat and lost.

How is an electric current made? The machine for producing electrical energy from mechanical energy is the dynamo. Special forms of dynamos are sometimes called generators or magnetos.

The second diagram shows an electric dynamo replacing the pump in the water diagram, wires replacing the pipes, and a motor at B replacing the water motor. Now, of course we know that a system such as this will not run without a supply of energy from the outside, for energy cannot be created by any system of machines. The dynamo is turned by an outside force, just as the water pump is. The force may be supplied by an engine, by a water turbine, by a windmill, or by any other type of machine designed to do work.

The dynamo and motor look exactly alike in the diagram. An electric motor is different from a dynamo only in minor respects. Many motors might be used to generate current; many dynamos might serve as motors.



As the first loop of wire is turned, an alternating current flows from the slip rings to the brushes. When the second coil is turned, a pulsating direct current flows from the commutator.

The outer part of the dynamo is composed of an electromagnet, curved so that its poles almost encircle the inner parts of the dynamo. Inside the electromagnets are many coils of wires, which move through the magnetic field of the electromagnets. The ends of the wires of the coils are attached to rings which, in turn, are in contact with carbon or metal strips called brushes, through which the current is carried into the wires. The outer magnets are called the field magnets, and the rotating part is called the rotor.

The dynamo usually provides current to operate its own electromagnets. The first time it is operated, a storage battery magnetizes the iron cores of the magnets. After this, there is a trace of magnetism left in the metal, sufficient to start a weak current flowing, which is used to build up the magnetism of the field magnets.

What causes the current to flow? You are familiar with the principle that when a conductor cuts a magnetic field voltage is generated which may produce a current. The dynamo works upon this principle. A current flows when the electrons in the coils are pushed along by the magnetic field.

If a coil of wire is rotated between two magnets, the current will flow one direction through half the rotation and the other direction through the other half of the rotation. Such a current, which changes direction, is called an alternating current and is delivered when the rings at the ends

of the coils are two circles. Such complete circles, one on each end of the system of wires which make up the rotor, are called slip rings.

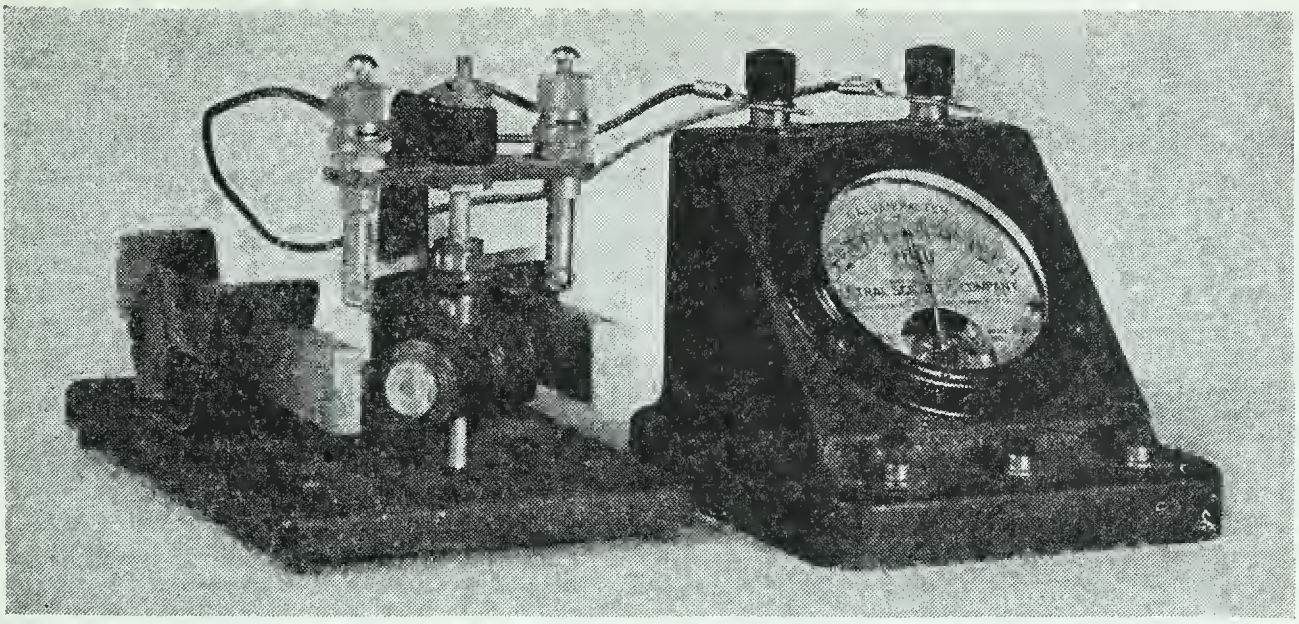
If it is desired that the current which flows from the generator shall be direct, a single ring is used, but it is split lengthwise. To each half ring, one end of the wire is attached. This device, called a commutator [kŏm′ū·tā′tẽr], causes the current to flow from the rotor through the wires always in the same direction.

What are some common types of power plants? The steam engine, the Diesel engine, or the steam- or water-driven turbine is used to provide energy to operate dynamos for city lights. The size and number of dynamos used depends upon the amount of current needed. Several dynamos are so perfectly kept in step that alternating current from two or more dynamos may flow at the same time through a wire. Because of this marvelous timing of dynamos and because there are usually several power lines interconnected, large cities are rarely without electricity, even though an accident, such as fire or lightning, may cause one dynamo to go out of operation.

The problem of farm lighting is different from that of the large city. Power from gasoline engines, windmills, or running water drives farm lighting-plant dynamos. These sources of power are not available for steady use. Operation of a gasoline engine is expensive. Wind does not blow at all times. Water must be stored in dry seasons to last until more rain falls. Because of the uneven supply of power, it is necessary to use storage batteries.

The standard farm power plant is a direct current dynamo which produces 32 to 40 volts of pressure and which charges a series of storage batteries. The usual voltage of farm lighting systems is 32 volts, compared with the typical city voltage of 110 volts.

Cheap and rather ineffective 6- and 12-volt windmill lighting plants are sold to charge batteries for radios and to operate one or more small lamps. These plants are more satisfactory than being without electricity, but are not strong enough to supply energy for any really effective lighting system.



The St. Louis motor is arranged to be used as a dynamo. The resulting current is measured by use of the galvanometer.

The automobile generator is a simple dynamo, turned by the energy of the automobile engine. It may produce current to be used directly, or it may charge the storage battery with which every automobile is equipped. Automobile electric systems operate at 6 volts.

What are magnetos? A magneto is a dynamo equipped with several permanent magnets. The country telephone, in which the bell is rung by turning a crank, has a magneto which makes the current. Small gasoline engines, such as those used for farm power and for outboard motors, depend upon magnetos to provide the spark for igniting the gasoline. These motors must be spun or cranked in some way to start the generation of electricity to operate the engine.

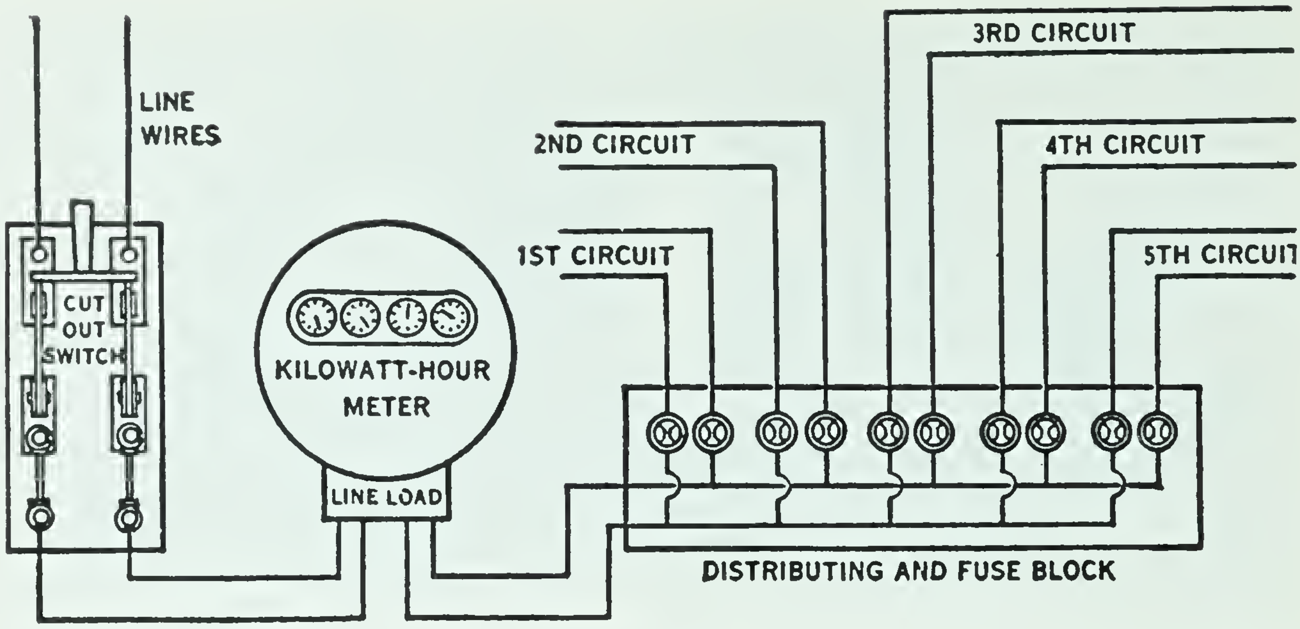
Demonstration. How Does a Dynamo Operate?

What to use: St. Louis or other simple motor, galvanometer, wires.

What to do: Put into the motor the permanent magnets and direct current rotor. Attach the binding posts to the galvanometer. Whirl the rotor between the unlike poles of the magnets, and use the galvanometer to measure the current produced. Whirl the rotor in the opposite direction.

What was observed: Describe how a current was produced.

What was learned: Explain how a coil and magnetic field were used to produce a current.



The current flows into the house through the line wires. It passes through the meter to be measured. From the distributing and fuse block as many circuits lead to the house as are needed. Note that each circuit is wired in parallel to the main line wires and that each wire is connected to a fuse.

Exercise. *Draw a diagram showing the parts of a simple direct-current dynamo. Label the diagram with these words:* Rotor, Magnets, Magnetic Field, Commutator, Brushes. *You may refer to drawings in this problem for assistance.*

Science activity. Make a simple motor. You can obtain kits at the dime store or make your own, following instructions found in books on mechanics for boys.

5. How is electricity carried?

We know that electricity is carried through wires. We need to know what kinds of wires are used and how they are connected to carry electricity safely.

What is a circuit? A circuit is a closed system of conductors through which a current flows. The current flows from its source, which may be cells or dynamos, through wires and closed switches, to magnetic coils or resistance wire where the energy is given off. If the current flows through a circuit from which resistance has been removed, the result is called a short circuit.

Conductors are of metal. Although silver is the best conductor, it is weak and expensive. Copper is almost as good a conductor as silver, is fairly cheap, and is durable and

strong. Conductors are insulated to keep the current within the circuit. Cloth and rubber are used to insulate lamp cords. In the iron cord, cloth and asbestos are wrapped outside the rubber insulation. Rubber should not be used in iron cords or other conductors which are near heated bodies, stoves, and heaters. Wire may also be insulated with varnish. Varnish is thin enough to permit wire to be wound cn coils with the turns close together. Spun glass is now being used for insulation.

Insulated wires are frequently run through pipes or wrapped with steel to protect them from wear, breaking, weather, and animals.

Circuits are controlled by switches. A switch contains a piece of metal which moves to open and close the circuit. A push button or knife switch is simply a strip of metal, fitted against metal contacts, and more or less protected. Other switches are more complex and are operated by tumblers, chains, and buttons.

Knife switches are dangerous and should be handled with extreme caution. Their advantage is that they carry a heavy current without loss of energy.

How do we protect against short circuits? If for any reason a current flows through the circuit without sufficient resistance, a short circuit results. If the insulation of a lamp cord is worn from the wire, the wires may come into contact with each other, and the current may flow directly from one wire to the other without going through the lamp. Without the resistance of the lamp in the circuit, a strong current flows, and the wires become hot. They may become so hot that the insulation burns, setting the house on fire. Short circuits may cause serious shock to anyone who may come into contact with the wire. Wires may come into contact with water pipes or other metal connected with the ground, and current may flow into the earth, causing a short circuit.

A fuse is a device which protects our houses from destruction when an accident occurs to the circuit. It consists of an easily melted wire in a case. As you know, too much current causes wires to become hot. The fuse is placed in the circuit. When the current increases beyond a safe point, the fuse wire melts, the current is cut off, and no harm re-

sults. Fuse wire melts so easily that you can melt it with the flame of a match. The size of fuse we use depends upon the amount of current in a circuit. The unit for measuring a flow of current is called the ampere. Fifty-watt lamps use about one-half an ampere of current; irons use about 5 amperes of current. Small motors use about 2 amperes. Thus, a current of five 50-watt lamps, an iron, and a washing machine motor added together would total about 10 amperes. A fuse which would just carry this current would melt out if another lamp were turned on.

The up-to-date method of protecting a circuit is by the use of a circuit breaker. They can be obtained for any size in use in a home. Fuses have to be replaced, but circuit breakers are merely reset.

Correct sizes of fuses must be selected to safeguard the circuit. House fuses range in capacity from 5 to 30 amperes. If you had a 50-ampere fuse in the circuit attached to your refrigerator motor, and a power line fell on your house circuit during a storm, the insulation would be burned from the coils of the motor before the fuse would melt. Replacing fuse wires with pieces of copper wire or with pennies is a dangerous and costly practice.

How do parallel and series wiring systems compare? There are two methods of connecting electrical devices. If the current flows through first one device, then another, then another, the connection is called series. Some Christmas-tree lights are connected in series. When one lamp is unscrewed or burned out, the entire string of lights goes out because the circuit is broken. In Christmas-tree lights this arrangement has value from the safety standpoint, for if something happens to the lights the current probably will not set the tree on fire.

In house-wiring this system would have serious disadvantages. All the lights in the house would have to be turned on or off at the same time. If one burned out, it would be necessary to try replacing each one until the burned-out lamp was found. Because resistance to the current would increase each time another lamp was added, the more lamps used, the less light there would be available.

To avoid the many difficulties of series wiring, the parallel

system of wiring is used. In this system, two wires are run through the house, side by side, each connected to the power line from the dynamos of the station. To connect a lamp, the wires of the lamp are attached to each of the power wires. Current flows across, from one wire to the other, through the lamp. Any other device may be attached at any point along the wires without affecting the lamp in any way. A toaster may be connected at another plug, a radio at another. Each uses the amount of current it needs, for each device resists the current flowing through it.

When many devices are connected in the parallel system, the current of each device comes through the power-line wires. Thus these wires must carry the total current used by all the devices in the circuit. If too many are in use at one time, the power line may be heated or the power-line fuse may melt.

What are grounded connections? There are some systems of wiring which use only one wire. Some country telephones and automobile wiring systems are one-wire systems. One connection is grounded. That is, the earth completes the country telephone circuit; and the automobile frame completes the automobile circuit.

Lightning may be grounded so that it becomes harmless. Lightning rods, made of heavy copper, are placed on the roofs of buildings and connected with the moist earth with heavy copper cables. The current of the lightning does not melt the cables and is conducted to the ground.

Demonstration. How Are House Lights Wired?

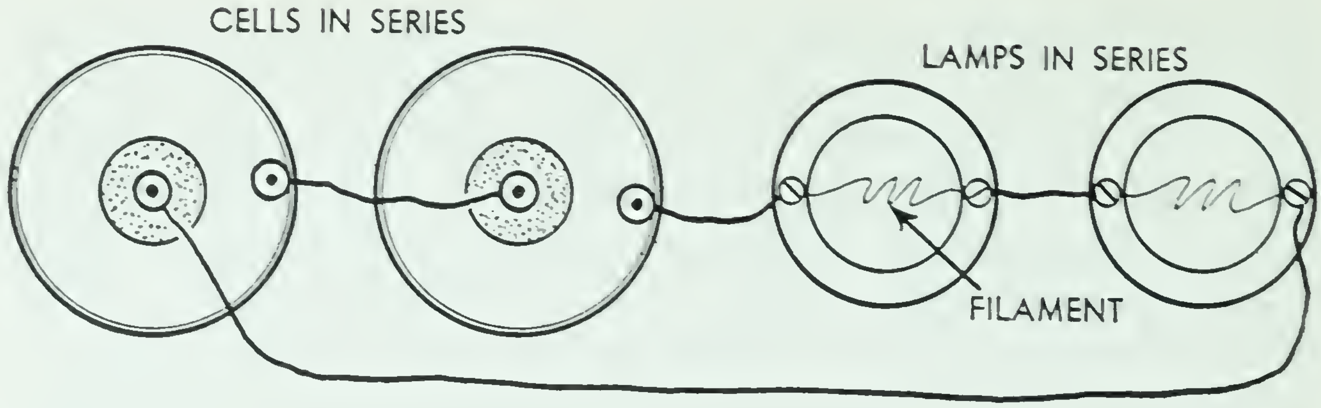
What to use: Three miniature lamps and sockets, two dry cells, wire.

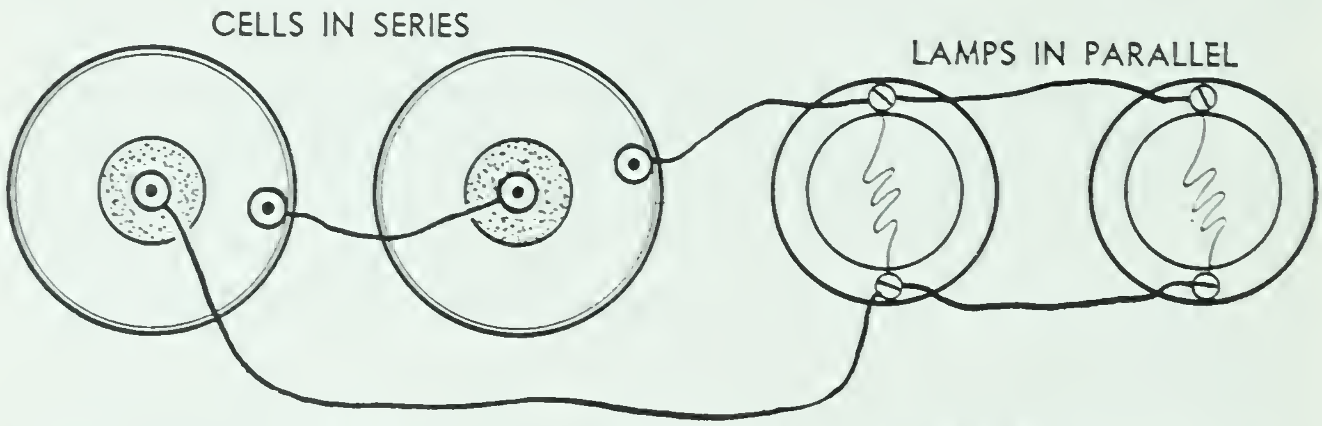
What to do: Connect the cells and lamps in series, as shown in the upper diagram on the next page. Unscrew one lamp. Add a third lamp to the series. Observe any change in brightness.

Set up the lamps in parallel, as shown in the lower diagram. Unscrew one lamp. Add another lamp to the circuit.

What was observed: How is each system affected by turning out one lamp? How is each system affected by adding another lamp?

What was learned: What are the advantages of parallel over series wiring for houses?





This is a top view of lamps in series and in parallel. Lamps in series are used for some Christmas-tree lights. Lamps in parallel are used in house-lighting. Set up each kind of circuit, and learn the advantages of each system. Leave out one light in each circuit and observe what happens.

Exercise. *Complete the following sentences:* A —1— is a closed system of conductors through which a current flows. Lamp cords are insulated with —2— and —3— to prevent loss of current. The best conductor, considering strength and cost, is —4—. When the current goes through the circuit without going through sufficient resistance, a —5— results. The wire in the —6— melts and shuts off the —7—. When a circuit has only one wire, one connection is —8—. —9— conduct lightning to the ground.

Science activity. Learn the location of the fuses in your house, and discover what devices are protected by each fuse. Before changing fuses, open the main switch. What does this do to electric clocks?

6. How is electricity measured?

When we measure the flow of water, we may measure the pressure, or the number of gallons of water per minute. The flow of water is determined by the amount of water available and by the resistance to its flow in the pipes. Similarly, we can measure the flow of electricity in two ways.

The pressure is measured in volts. The rate of flow of current is measured in amperes. The resistance is measured in ohms.

When we change the resistance to the flow of water by opening or closing a faucet, we obtain a greater flow of water as the resistance to the flow decreases. We cannot affect the pressure greatly by turning the faucet on or off. Neither do we greatly affect voltage by use of ordinary electrical appliances.

What is Ohm's Law? The relationship between the flow of current, the electromotive force, or pressure, and the resistance is expressed in a mathematical formula called Ohm's Law. It is:

$$\text{Amperes} = \frac{\text{Volts}}{\text{Ohms}} \text{ or Volts} = \text{Amperes} \times \text{Ohms},$$

$$\text{or Ohms} = \frac{\text{Volts}}{\text{Amperes}}$$

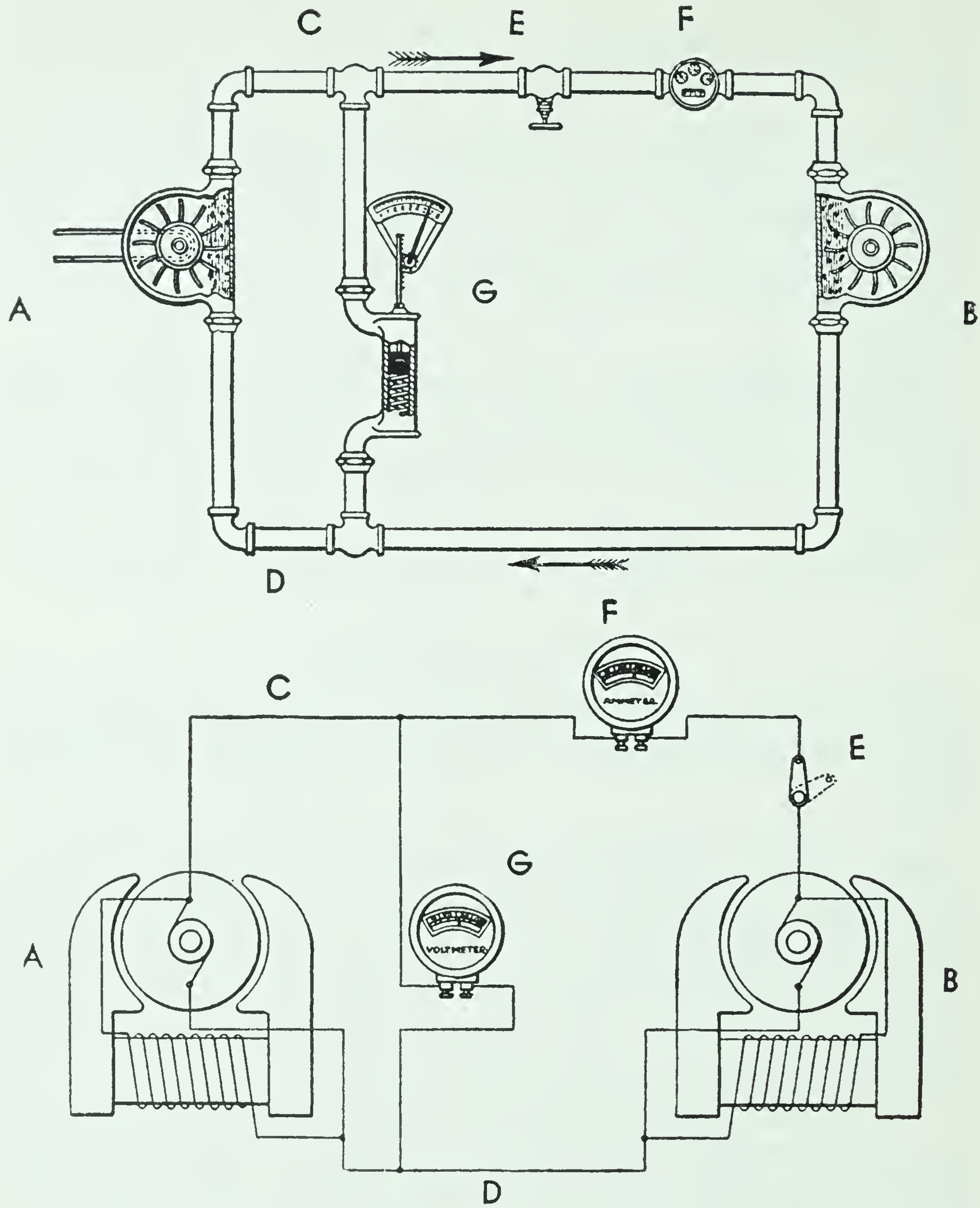
If you are studying mathematics, you recognize these three ways of expressing the formula as stating identical relationships.

It is best to memorize the formula as it is stated first.

The units are difficult to define. The ohm is the resistance of a certain sized thread of mercury in a tube about a meter long. The ampere is the rate of flow of current that deposits a certain amount of silver from solution in a given amount of time. The volt is the pressure that keeps one ampere flowing through a resistance of an ohm.

How do we measure electrical power? The flow of current at a given voltage represents a definite amount of power. The name of the unit of electrical power is the *watt*. The number of watts is equal to the volts times the amperes.

Let us consider the comparison of the flow of current with the flow of water. The water pump A (top of page 200) produces a current of water at a certain pressure, flowing through the pipes C and D. The current is used to turn a water motor B. The flow of current is measured by the meter F, and the difference in pressure between the pipes is measured by the pressure gauge G. The flow of water is regulated by the valve at E. If the motor receives a flow of a gallon of water a second at a pressure of 10 pounds per square



Pressure of water is measured by a gauge, and flow of water by a meter. Pressure of a current is measured by a voltmeter, and flow of current by an ammeter. Study the text on pages 199 and 201 until you know what each letter means. Note that the coils of the motor and dynamo are wired in parallel.

inch, a certain amount of work may be done. If the pressure is doubled to become 20 pounds per square inch, a half gallon of water per second will do the same amount of work as before. If the pressure is reduced, the valve would have to be opened to cause more water to flow.

In the second diagram, a dynamo A produces the current. The motor B changes the current to work. The current is carried through the wires C and D. The pressure is measured by the voltmeter at G, and the current by the ammeter F. The switch E permits the current to be turned on or off.

The difference in pressure between the wires exists whether the motor is running or not. If the switch is closed, a current flows through the wires and motor. Both the pressure and the amount of current determine how much work the motor can do.

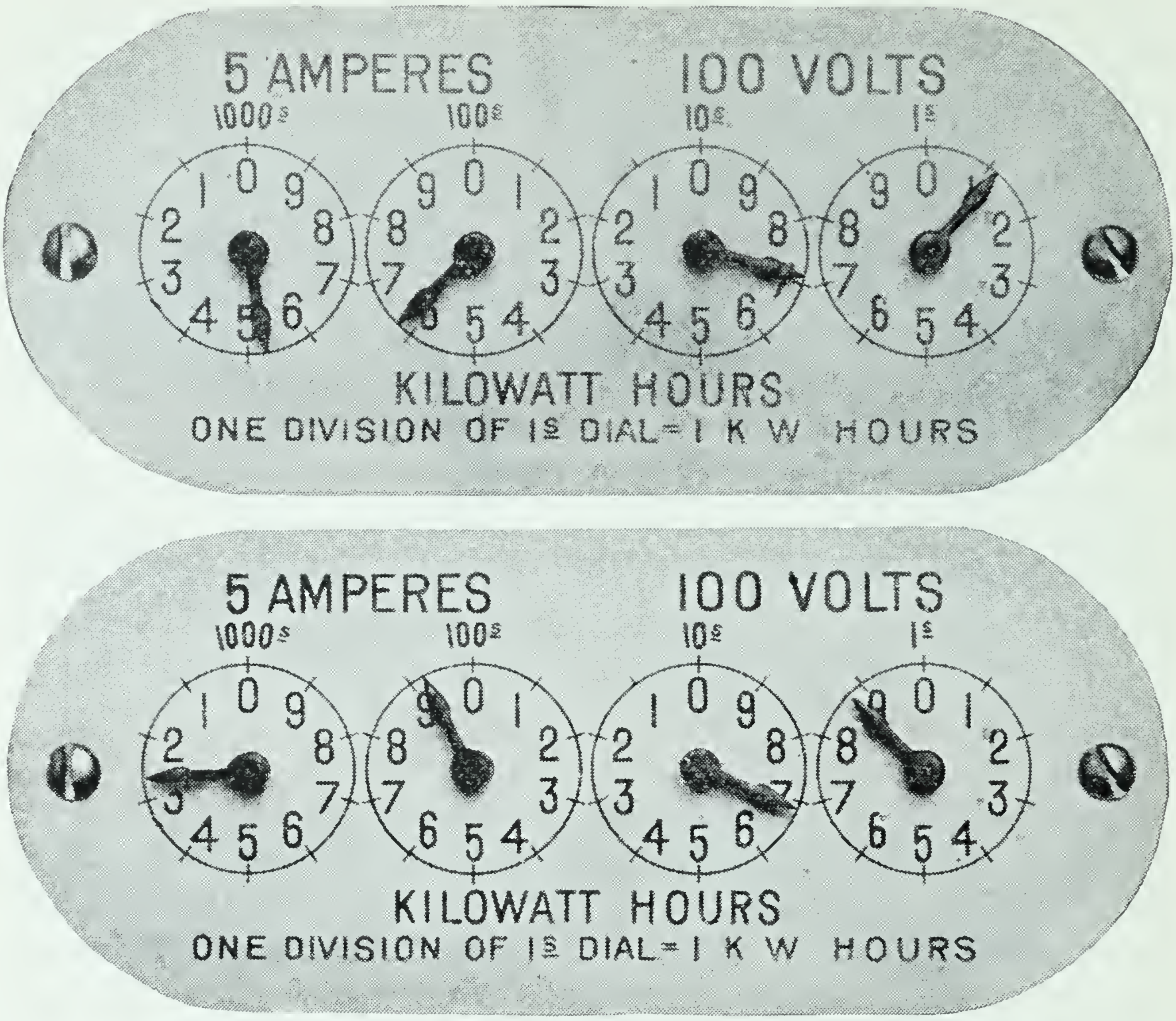
A pressure of 110 volts, providing a current of 2 amperes through the resistance of the motor, will do work at the rate of 220 watts. If a current of 220 volts is used, the resistance of the motor may be increased so that a current of 1 ampere flows, and the motor still does work at the rate of 220 watts. The watt is a unit of power, and power is the rate of doing work.

The number of watts of power that can be obtained from a current depends upon the amount of power used to produce the current. The dynamo can put out no more work than is put into turning it. We cannot obtain unlimited amounts of power from a current merely by reducing the resistance to let more current flow.

How is measurement of electricity useful? Use of electricity depends upon making devices to use it in the right amounts. If we have a 100-watt lamp on a 110-volt circuit, we can determine the number of amperes used thus: Since Watts $=$ Volts $\times$ Amperes, $100 = 110 \times$ Amperes, or .909 amperes.

We may next find the resistance of the lamp from Ohm's Law. Since Ohms $= \dfrac{\text{Volts}}{\text{Amperes}}$, we solve the problem thus: Ohms $= \dfrac{110}{.909}$ or 121 ohms. The resistance of the lamp, when it is using 100 watts of current, is 121 ohms. However, the resistance of a hot filament may be as much as 14 times as much as that of a cold filament, and as a result a 100-watt lamp does not always use 100 watts of current.

What does the electric meter measure? We now know how the rate of flow of current is determined for the various



The reading at the top is 5671 kilowatt hours. What is the reading of the meter below?

devices. Each uses a current determined by its resistance.

When we pay the light bill, we buy a certain amount of energy, as measured by the meter. The meter reading is in terms of kilowatt hours. A kilowatt hour is one thousand watts of electricity flowing for one hour. That is, you may use ten 100-watt lamps or twenty 50-watt lamps for one hour, and the energy used will be recorded on the meter as one kilowatt hour.

The meter contains a motor which turns the hands on the dials of the meter. The first dial at the left indicates 10,000 kilowatt hours, the second dial 1000, the third dial 100, and the fourth dial 10 kilowatt hours. Units are read on the last dial. The highest reading the kilowatt hour meter can give is 9999 kilowatt hours.

You will note that the figures on the first and third dials

run opposite the direction of the clock figures, while those of the second and fourth dials run in the same direction as do the figures of a clock. It is easy to read these dials, however, for you need remember only that each hand moves from the smaller to the larger number. You read the smaller number when the hand is between two numbers.

The meter reader carries with him a book in which he writes down your meter reading each month. By subtracting the reading of last month from the reading for this month, the number of kilowatt hours you use is determined. The number of kilowatt hours is multiplied by the cost per kilowatt hour. Current cost may vary from 2 to 10 cents per kilowatt hour.

The cost of current is determined by many things. The source of power—whether steam, Diesel engine, or water—is one factor. The average length of power line per customer, the amount of power each customer uses, the amount of service demanded by customers, and the business success of the company are other factors.

Demonstration. How Is Electricity Measured?

What to use: Two dry cells, iron and copper wire, pocket voltammeter (battery tester), file, ruler.

What to do: Measure the voltage of the dry cells. Measure the current in amperes. The resistance of the materials inside the cell and the resistance of the tester determine the reading in amperes.

Attach an iron wire to one of the binding posts of a cell. Clean the wire with the file to insure good contact. Measure the current exactly one foot from the binding post. Repeat with two cells in series and with copper wire.

What was observed: Make a table of the measurements you obtain. Calculate the resistance of the wire. Do not forget to subtract the resistance of the tester and cells.

What was learned: How does the resistance of various wires differ? How is a current measured?

Exercise. *Complete the following sentences:* Resistance is measured in —1—, the flow of current in —2—, and the electromotive force or pressure in —3—. Ohm's Law is —4—. The amount of energy in currents is measured in —5—. Watts equal —6—. The unit of measuring current for paying the light bill is —7—. Three 50-watt lamps burning three hours a day for 30 days use

—8— kilowatt hours of current. At five cents a kilowatt hour, this current would cost —9—.

Science activity. Learn to read your electric light meter. Keep accurate records of the current you use, and check the light bills.

7. How is electricity used for heating?

Why does the wire in the toaster get hot when the wire in the cord does not? Why does the wire in the electric lamp get hotter and give off less heat than the wire in the toaster?

What causes heat in a circuit? Heat results when a current overcomes resistance. If you put a piece of fine copper wire across the posts of a dry cell, it becomes hot enough to burn itself in two. A piece of iron wire, of the same size and length, becomes less hot than the copper wire. Iron has greater resistance and permits less current to flow than does the copper wire. A smaller current produces less heat than a large current.

If the wires are tied end to end so that the same current flows through both, the wire then becomes hotter where the resistance is greater, the current being equal.

Every conductor is also a resistor. Poor conductors, such as nichrome and German silver, offer more resistance than do such good conductors as copper and aluminum. Wires small in diameter offer more resistance than do thicker wires. That is why filaments in lamps are small. Long wires offer more resistance to currents than do short wires. It is best to place machines as near the power plant as possible to save energy loss.

What happens to lost energy? Energy not used for useful heating is lost. Every wire is heated to some extent, and the heat is wasted. Energy is lost through poor insulators and short circuits. By using high voltages, large wires, and careful placement of power plants, power loss may be reduced.

How does the electric light work? The electric light is a heating device. Less than 10 per cent of its energy is radiated as light, and the rest is lost in heat. Light is produced because the filament is heated to *incandescence.* The fine filament of tungsten wire offers high resistance to the current, permitting a small current to flow. The wire becomes very hot because of its small size. Filaments in gas-filled lamps

are coiled in such a way that each turn of the coil keeps those next to it warm. The vacuum in small lamps reduces heat loss. In a vacuum, however, the filament vaporizes rapidly and blackens the bulb. Lamps of less than 50 watts contain vacuums, and those larger than 60 watts usually contain nitrogen or argon gas.

How do heating devices work? The electric iron, next to the electric light, is the commonest electrical heating device. The electric iron is made up of a coil of nichrome wire. Nichrome withstands high temperatures and resists oxidation well. This coil of wire is placed within the iron, between the upper and lower parts. The coil is insulated from the iron with mica and asbestos.

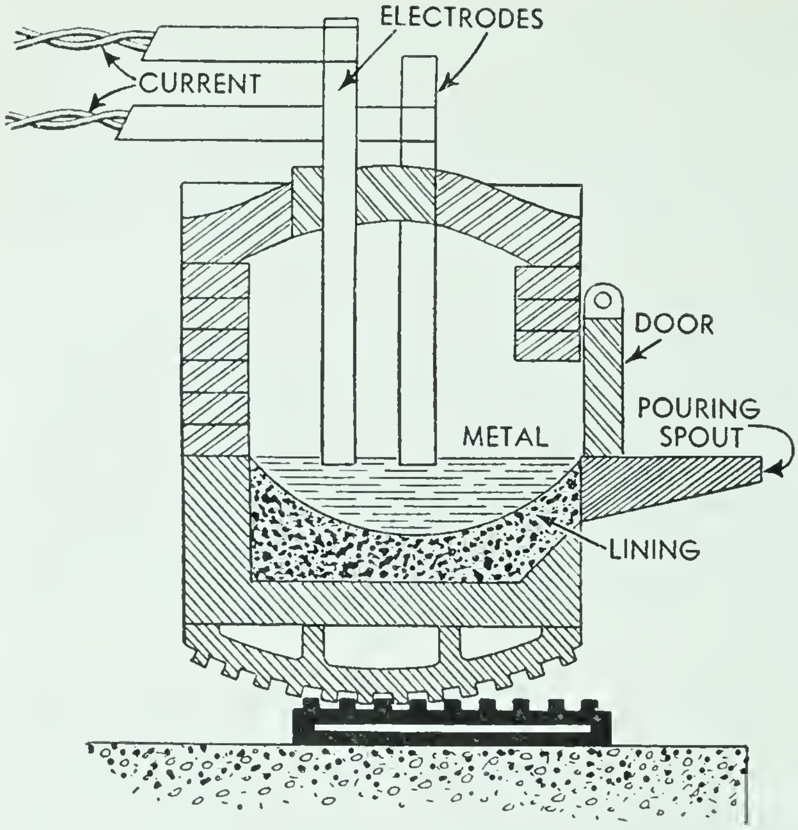
The temperature of the iron is controlled by a thermostat. A thermostat is a safety device of the greatest importance, for with it the iron is less likely to become overheated and start a fire. The temperature of the iron is kept below the kindling point of cloth. The cloth may char, but it will not ordinarily burn. Even so, it is important not to leave a connected iron unwatched.

All the common electrical cooking devices are made up of the same type of coils that are used in the iron. Since the coil of wire is exposed in the toaster, the heat is given off by radiation. The coils in the percolator and waffle iron are covered, and heat is carried by radiation and conduction to the food being cooked.

The electric stove is largely a framework which supports simple heating coils. There are two types of coils. The open type is less expensive but has the serious disadvantage of being exposed to food spilling and of being a possible source of fire or shock. The other type of heating unit has a coil enclosed in a metal tube, which protects the wire from liquids and oxidation and prevents shock and fire.

The electric stove is usually operated on a different circuit, providing current from three wires, which provides power from two 110-volt circuits. A current of 220 volts is advantageous for use with a stove. To keep the danger of shock at a minimum, the metal of the stove must be insulated from the electric wires.

Electricity is rarely used for house-heating, except in



In this electric-arc furnace resistance is provided by the materials placed in the furnace. The furnace is made of firebrick and other materials which resist heat. Equipment is provided for tipping the furnace to pour out the melted metals.

spring or fall or where current is inexpensive. The usual heater is a portable coil placed in a reflector. In some houses a heating coil is built into a wall reflector.

Most driers are combinations of heating coils and electric fans. Driers are used for the hair, for hands and face in public washrooms, for photographic prints and films, and for industrial processes.

What is an electric furnace? The electric furnace which is used to melt metals and to make carborundum produces the highest temperatures available to man. It consists of a box or furnace of fire-resistant brick. Two carbon rods project into the furnace. The rods come together, and a current flows through the rods where they touch. The relatively poor connection heats them until they vaporize. Then the rods are slowly moved apart, and the current is carried by the carbon vapor. Such a gap filled with heated gas is called an *arc*. The arc furnace melts practically anything put into it. There is another type of furnace that uses the resistance of materials put into it to provide the resistance to cause heating.

How is electricity used in welding? One of the most important uses of electricity in industry is for welding metals together. One type of welding equipment employs an arc, and the materials to be welded are melted together by the hot gas. The more common method is to press the pieces of metal together and run the current through them from each side. The resistance is greatest at the point of contact, and

Eugene Rosing photo

Electric welding is used in many types of repair work. The shield is used to protect the eyes from the intense ultraviolet light of the arc.

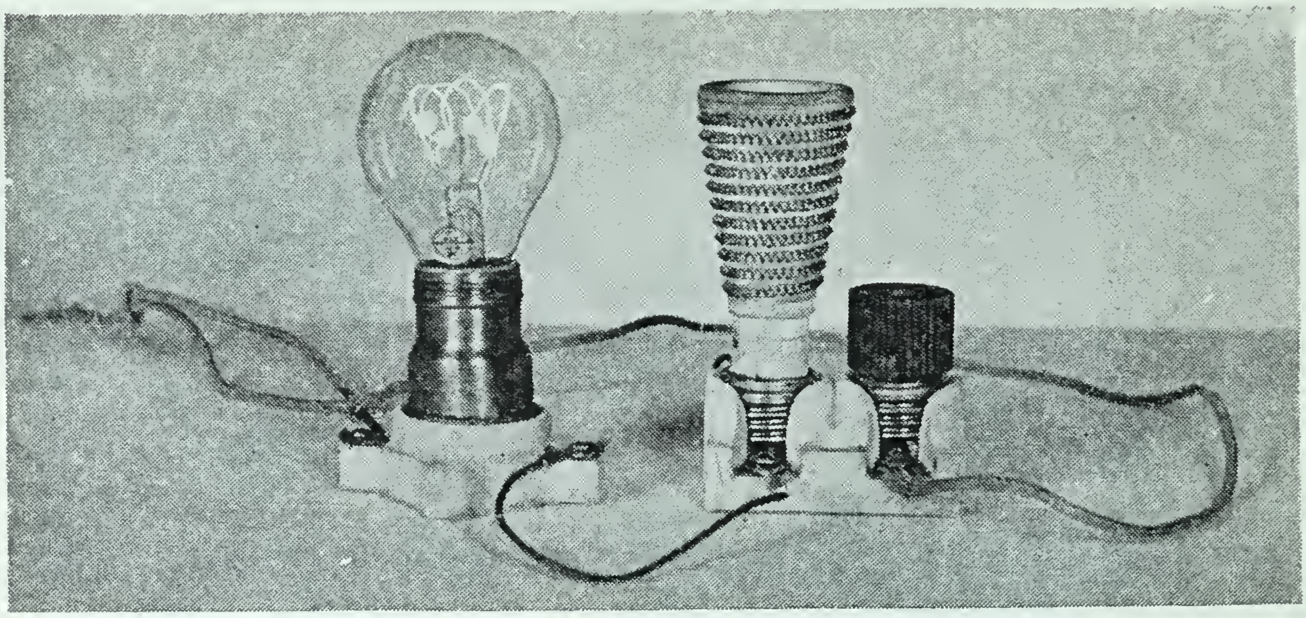
the metals melt from the heat. The heat and pressure used to hold the metals together cause them to be permanently joined. Welding is used in making washing-machine tubs, automobile bodies, streamlined trains, airplanes, chicken-wire fencing, and pipes and culverts. In fact, welding is rapidly replacing rivets in most industries. A current of low voltage and high amperage is used in welding.

Demonstration. What Part of a Circuit Is Hottest?

What to use: Lamp cord, light circuit, electric light, heating coil, sockets, dry cell, No. 30 copper and iron wire.

What to do: Connect the lamp and heating unit in series, as shown at the top of the next page, on a regular 110-volt light circuit. Be sure the connection is in series. Turn on the current. Dry the hand, and place it cautiously on the heating coil. Is the coil hot?

Remove the lamp from the circuit, after turning off the current. Connect the heating coil in the circuit. (*Keep your hands*



The heating coil does not become hot because the resistance of the lamp reduces the flow of current. The coil and lamp are connected in series. Why is the fuse used?

off!) Hold a piece of paper against the coil. Is the coil hot? Hold across the binding posts of the dry cell a piece of copper and a piece of iron wire.

What was observed: State briefly what you saw and felt.

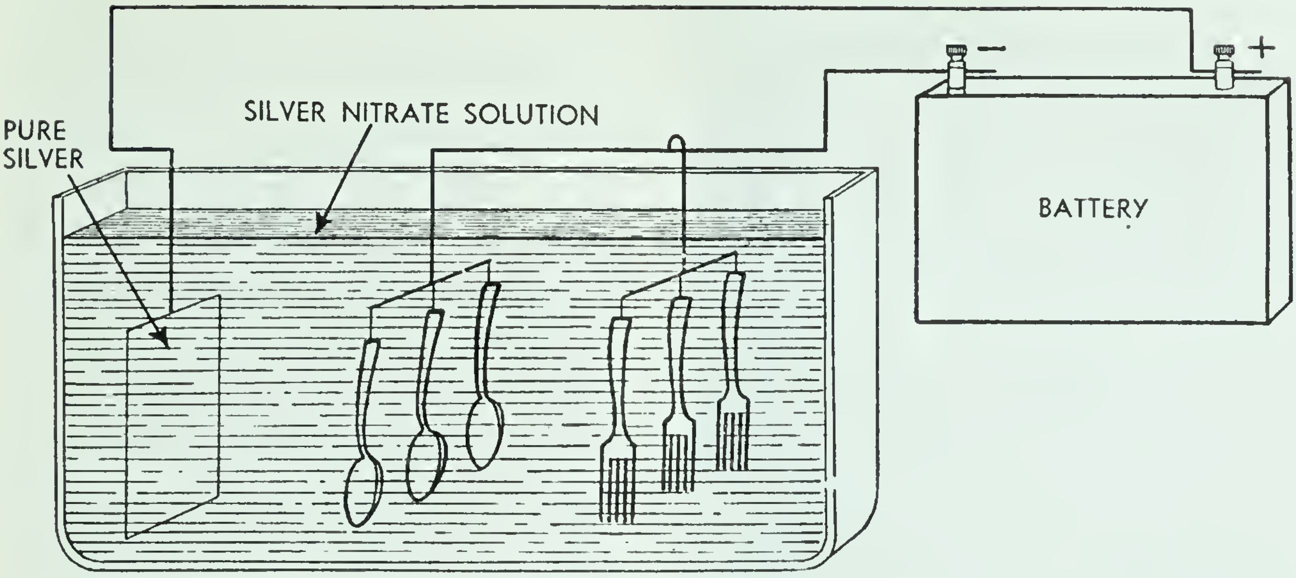
What was learned: Why does the coil remain cool with the lamp in series? Why does it become hot without the lamp? Which is hotter, the lamp filament or the coil? Which is a better conductor, copper or iron?

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* nichrome, resistance, arc, coil, varies, current, iron, light, conductor, heat, length, size, series, parallel.

Science activity. For your next science-club feed, electrocute your hot dogs. Drive nails through a board in pairs, and wire the heads of the nails to a push-in plug. Complete the circuit by forcing a weiner down on the nails. Plug it in. When the dog is hot, disconnect the current. Several pairs of nails may be used on one circuit, wired in parallel. Have mustard and buns on hand to complete the test. (*Don't touch the apparatus when it is plugged in!*)

8. How is electricity used in the chemical industries?

Every time you eat from a silver plated spoon or cook in an aluminum kettle, you are dependent upon a chemical use of electricity for the goodness and cheapness of the utensil you use. Electricity is used to make the chlorine used to



Silver plating is possible because electric currents can produce chemical changes. Silver is deposited from the solution upon the tableware, and the solution reacts with the silver plate to renew itself.

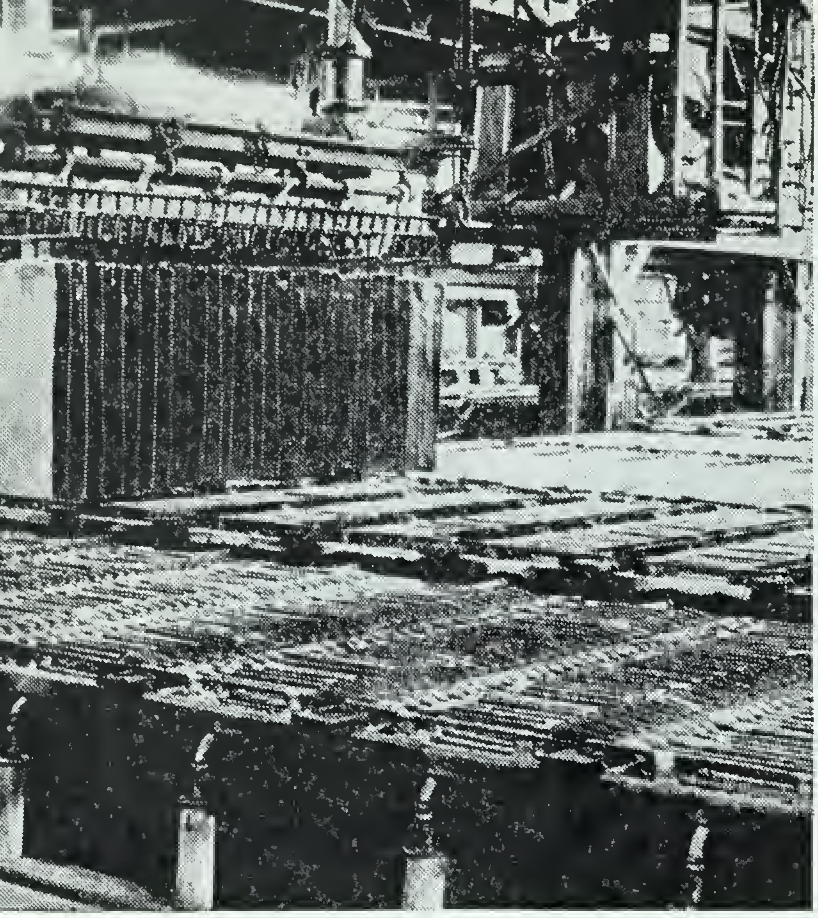
purify water and to make the lye used in soapmaking. Thus even cleanliness depends on electricity.

How is silverware plated? Your silver plated spoons are really iron, except for a coating of silver thinner than a sheet of paper. The spoon is pressed from iron and shaped with the pattern stamped on the handle.

To plate the spoons, a solution of silver salt is prepared, and a bar of silver is placed in the solution. The spoons to be plated are suspended in the solution from a bar. The bar of silver and the spoons are connected by wires to the posts of a cell or dynamo. The silver is attached to the positive post, and the object to be plated is attached at the negative post.

The electric current causes the silver in the salt solution to be deposited on the iron spoon. The acid part of the salt combines with the silver of the bar, keeping the solution at a uniform strength. The silver bar is gradually reduced in size as silver is deposited on the spoons. The amount of silver deposited determines the value of the silverware. A single thin coating, called a wash, looks at first as good as any other quality of plating, but wears off almost immediately. The best plated silverware lasts in ordinary use from 5 to 10 years, and it may last much longer.

How is copper purified? The method of purifying copper is very similar to the process of plating silver. When the copper ore is prepared by roasting and blowing air through the melted copper in a converter, the copper formed is im-



Courtesy International Smelting and Refining Co.

Pure copper is deposited from a solution to form the plates being removed from the tanks.

pure. A plate of pure copper is attached to the negative post of a battery or dynamo. The impure copper is connected to the positive post of the current source. Both pieces of metal are covered with a solution of copper sulphate. When the current flows, the impure copper goes into solution. Pure copper from the solution is deposited on the pure plate. The impurities settle to the bottom of the tank as "mud." This mud sometimes contains gold or silver.

How are book plates made? The plates from which this book was printed were formed by electroplating. The type, set by a linotype machine, and the pictures, made on metal blocks, were assembled in the form of pages. An impression was made by pressing waxlike material against the type. Copper was then plated over the impression in the wax plate, filling the hollow places left by the type with a thin plate of copper. Then the copper plate was removed, and type metal was poured into the letter forms to give them strength. The metal plates were set into the press, and the book was printed.

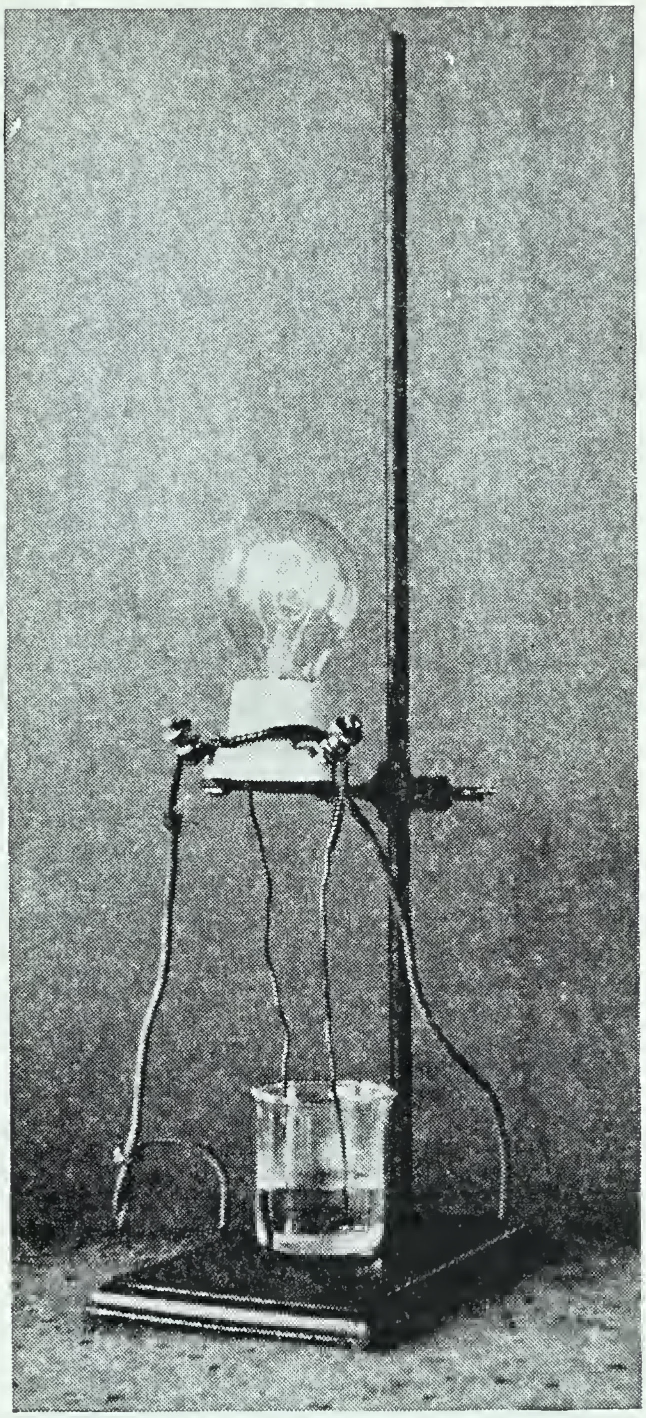
How is aluminum purified? The process of purifying aluminum is considerably different from that employed in purifying copper. Aluminum ore is dissolved in a mineral melted in an electric furnace. The aluminum ore dissolves in the liquid mineral and is separated into oxygen and aluminum by electrical means. The melted aluminum is drawn from the bottom of the tank, and more ore is added at the top. The electric furnace supplies heat to melt the materials, and also provides the current which separates aluminum from oxygen.

How are lye and chlorine made? Lye is a compound of sodium and water. Table salt is a compound of sodium and

chlorine. To make lye and chlorine, it is necessary to separate the sodium from the chlorine in table salt.

An electric current is run through a solution of table salt. The metal sodium is attracted to a negatively charged steel post in the solution. The sodium reacts with water, forming hydrogen and lye. The hydrogen gas passes off, and may be collected and put into tanks to be used for fuel for welding. The lye remains in the salt solution. When the solution is evaporated, the salt settles out first. Then the rest of the water is evaporated, leaving the lye behind. The lye is sold for making soap.

The chlorine is attracted to a positively charged carbon post in the salt solution. Chlorine is a greenish, bitter, poisonous gas. It is collected, dried, and pumped into tanks for use in purifying city water.



This simple apparatus gives a fairly accurate estimate of the ability of solutions to conduct electricity. The brightness of the filament is in proportion to the strength of the current.

What other chemical changes depend upon electricity? Electricity separates water into hydrogen and oxygen. Hydrogen is attracted to the negative post, and oxygen to the positive post, of an apparatus made for that purpose. Acid is added to the water to make it conduct a current, for pure water is a poor conductor. The volume of hydrogen is twice that of the oxygen collected in the tubes surrounding the electrodes or posts. The gases may be tested—hydrogen burning explosively when

mixed with a little air, and oxygen causing a glowing splint to burst into flame.

Solutions differ in their capacity to carry currents. Limewater and vinegar carry only small currents. Salt water and hydrochloric acid solutions carry current very well. Turpentine, alcohol, and oils do not carry currents. You can test the conductivity of solutions with the apparatus shown in the illustration on page 211.

Why do currents break up chemical compounds? When acids, bases, or salts are put into water, they break up to a slight extent into charged molecules or atoms. The hydrogen molecules and the metallic atoms or molecules have positive charges. The acid-forming elements break up into atoms or groups of atoms having negative charges.

Now, as you know, *unlike charges attract.* The positive post of a piece of apparatus attracts negative charges, such as are held by oxygen and the chlorine. The negative post attracts metals and hydrogen molecules because they carry positive charges. Whenever a charged atom or molecule touches a charged post, it loses its charge and goes out of the solution. Gases rise to the top. Solids either are deposited or react with the water or go back into solution.

It is apparent that only direct currents may be used in chemical separation of compounds.

DEMONSTRATION. HOW DOES ELECTRICITY PRODUCE CHEMICAL CHANGES?

What to use: Sodium chloride, litmus cubes, U-shaped calcium chloride tube, one-hole stoppers to fit, carbon rods from flashlight battery, dry cells and wires, support, copper sulphate, copper and lead strips, beaker.

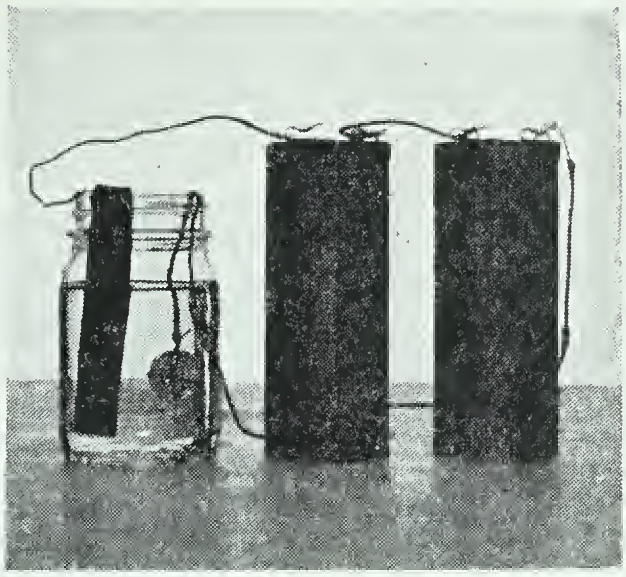
What to do: Dissolve a litmus cube in hot water. Into the water put a teaspoonful of salt. Pour the solution into the U tube, and support the tube so it will stand. Into each stopper put a carbon rod from a flashlight cell. Put the stoppers *loosely* into the U tube. Connect the carbon rods to two or more dry cells in series. Observe the color changes. Sniff cautiously at the side connected to the positive post.

Clean the lead strip or a foreign coin so that it is free from oil. Connect it to the negative post of two or more dry cells in series. To the positive post of the dry cell connect a clean copper strip.

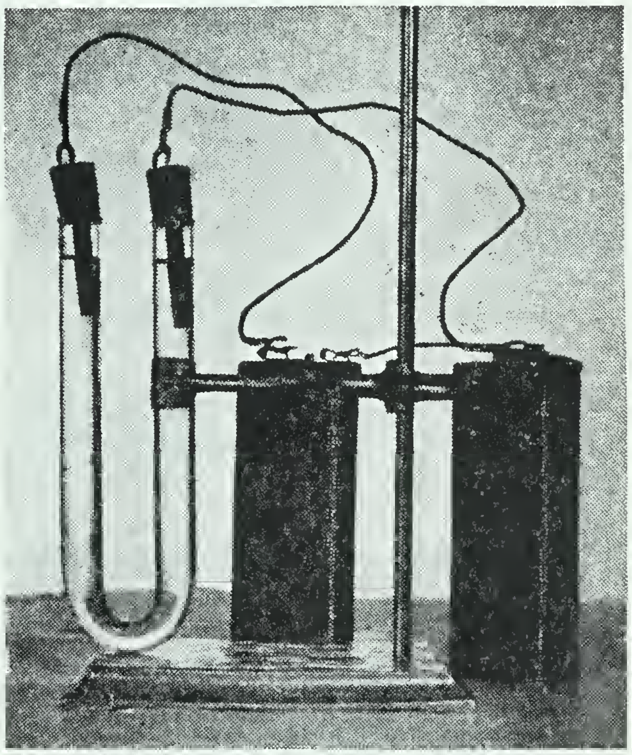
Prepare a saturated solution of copper sulphate—one-quarter pound to a pint of water—either by soaking the crystals overnight or by heating them in water. Put the lead and copper strips into the solution.

What was observed: Report what was observed in each part of the demonstration.

What was learned: What types of chemical change may be produced by an electric current? Why did the litmus solution change color? Is chlorine a bleaching agent? How do you know?



The upper setup is being used to copperplate a foreign coin. The lower apparatus is used to separate table salt into other chemicals.

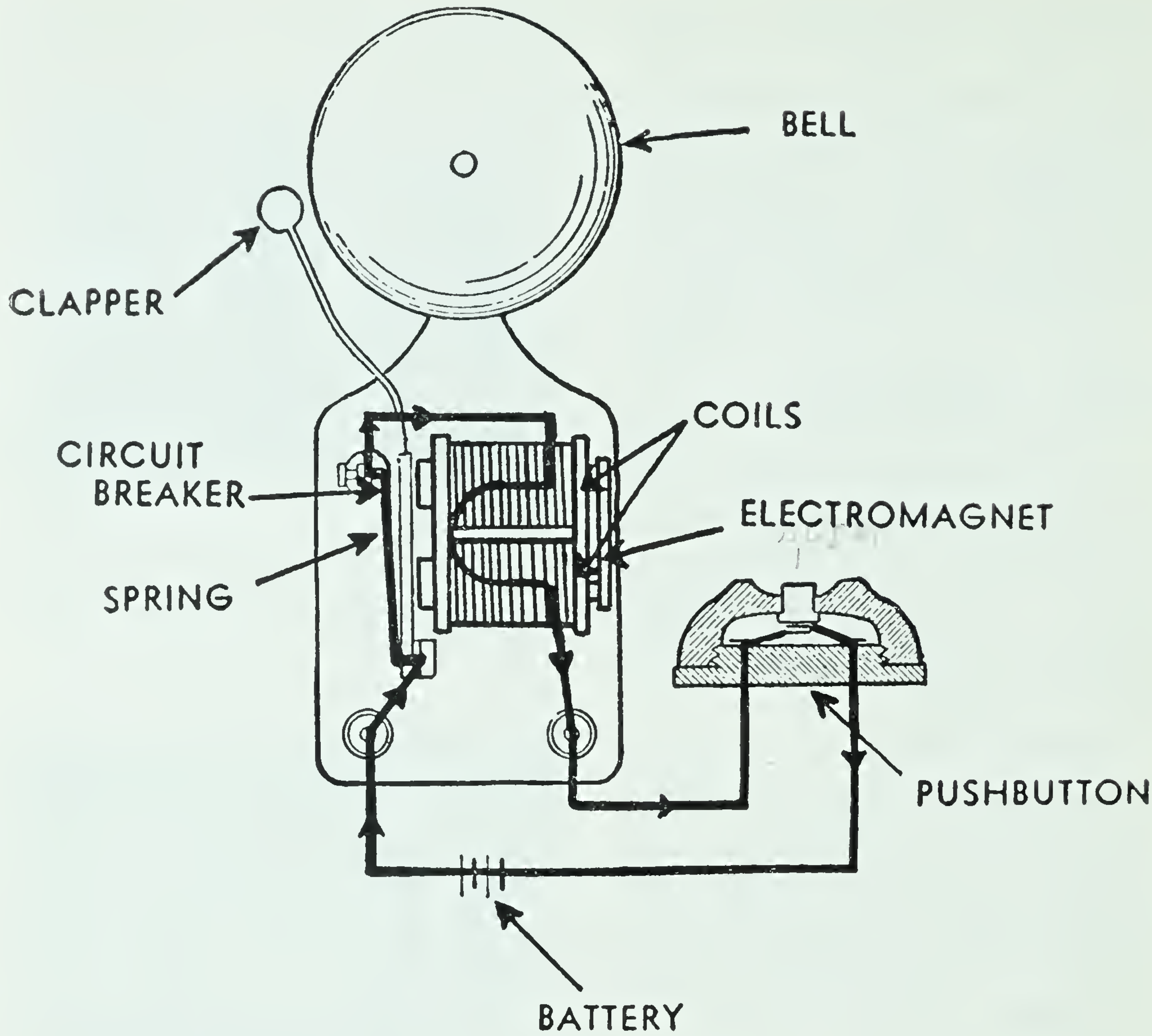


Exercise. *Write a paragraph summarizing this problem, using in it the following words:* positive, negative, metal, acid-former, lye, silverware, attract, charge, purify, chlorine, copper, hydrogen, electric current.

Science activity. Clean your silverware by electricity. Dissolve a teaspoonful of each salt and soda in a quart of hot water in a bright aluminum baking pan. Put the silver in the hot solution. As soon as the silver is clean, polish it with a soft cloth and a little whiting. The action of the metals and the salt produces the same type of chemical action in the pan that occurs in the wet cell and destroys the tarnish by electrical action.

9. How is electricity used to do work?

There are two common types of machines in which electrical energy is transformed into mechanical energy. One is the doorbell; the other is the electric motor. In both of these an electromagnet provides the energy to do the work.



The electric doorbell is one of the simplest machines using electricity to do work. The black line shows how the current would flow if the clapper were all the way back against the screw.

How does the doorbell work? The essential parts of a doorbell are the circuit breaker, the electromagnet, and the spring armature. When the push button is pressed, it completes the circuit and causes the current to flow through the insulated coils and to the screw or point of the circuit breaker. From the point of the circuit breaker, the current is carried through the spring and to the frame of the bell. Every time the circuit is closed, the coils become electromagnets which pull the clapper and break the circuit. The electromagnets then lose their power, and the spring pulls the clapper back, closing the circuit. The clapper moves rapidly back and forth because the electromagnets and the spring pull upon it alternately. Any bar which is attracted by an electromagnet is called an armature.

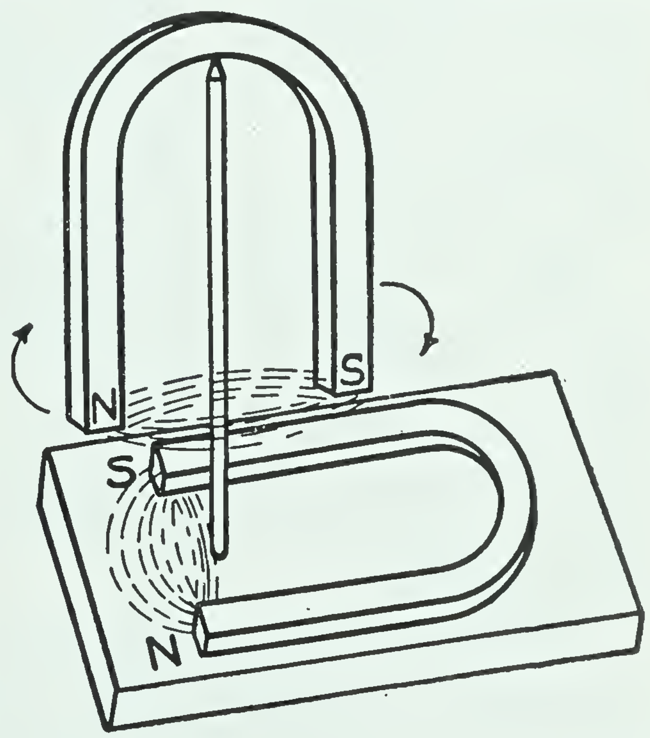
Some electric razors and hair clippers work on the same principle as the doorbell. In these instruments the vibrating bar moves a comblike set of knives which cut or shave off the hair.

How does the electric motor work? The electric motor works upon the principle that like poles repel and unlike poles attract each other. If you put two permanent magnets in the position shown in the diagram below, with the like poles of upper and lower magnets together, the pivoted magnet tends to turn in the direction indicated by the arrows until the north pole is directly over the south pole of the other magnet. It is impossible to make a motor employing permanent magnets, because when they once reach the position in which unlike poles are close together, the pivoted magnet comes to a stop.

The poles of electromagnets may be changed by changing the direction of flow of current through the coils. If we substitute an electromagnet for the pivoted permanent magnet, we can make the magnet turn again by changing its poles. This, essentially, is the plan of an electric motor.

The parts of a motor are the same as those of a dynamo. The outer magnets are called the field magnets and produce the magnetic field which passes through the rotor or armature. The armature is so made that it rotates between the poles of the field magnet and consists of coils of wire wound upon soft iron cores.

Current is conducted into the coils of the rotor or armature through carbon brushes. In the case of the direct current motor, the brushes are in contact with the commutator. The alternating current motor has slip rings instead of a commutator.



Like poles repel; unlike poles attract. Permanent magnets cannot be used in a motor because there is no way of changing their poles.

How is work done? The

poles of the rotor and the field coils are wound and connected in such a way that like poles are always near each other, and unlike poles are not near each other. The like poles repel, and the unlike poles attract, causing the rotor to turn rapidly.

As the rotor turns, the poles are changed by the changing direction of current.

To do work, the energy of the spinning rotor must be conducted to some machine which uses mechanical energy. The rotor turns upon a shaft. Tools may be connected directly to the shaft of the motor, or the power may be transferred to machines by use of gears or pulleys.

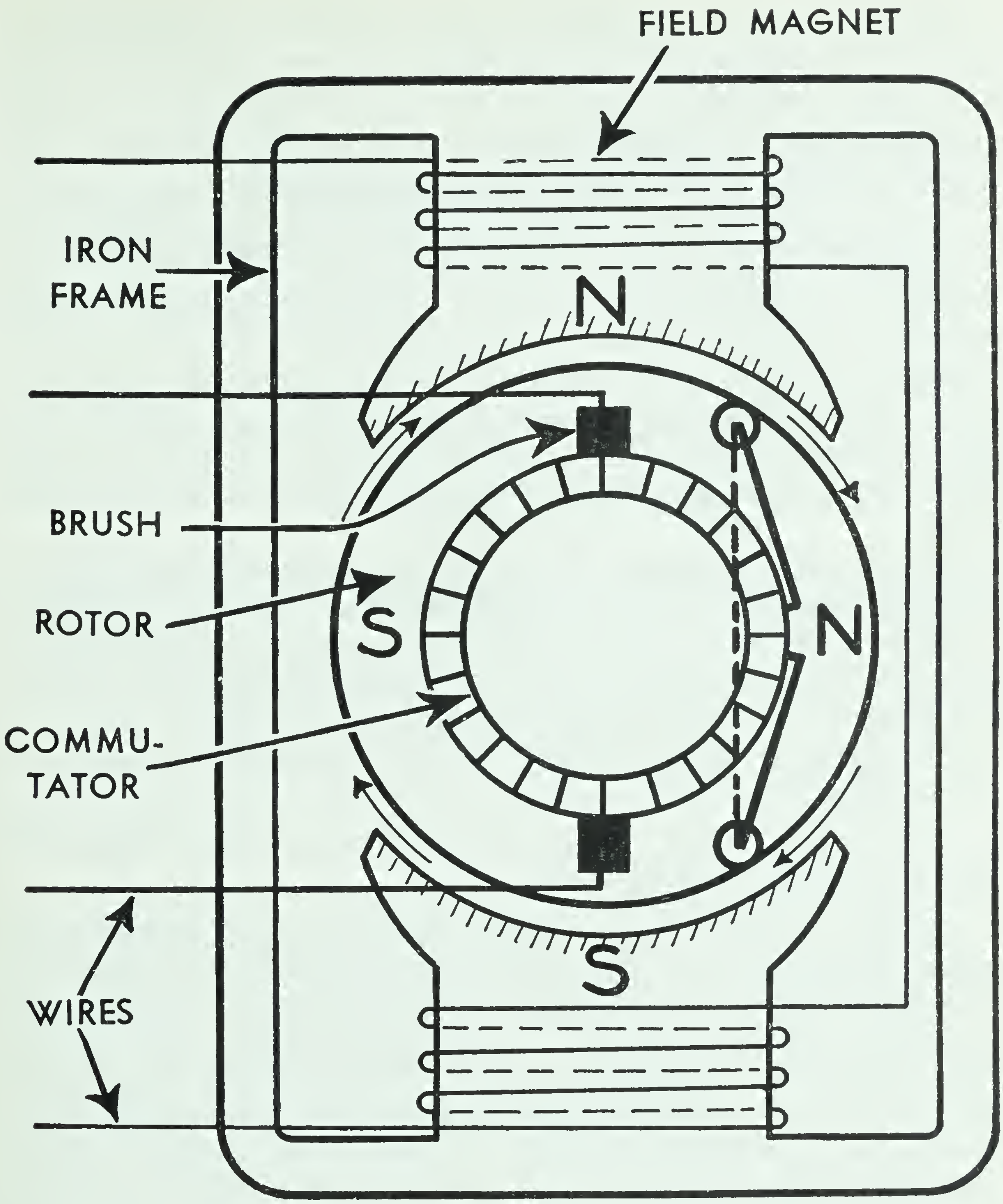
There are almost as many kinds of motors as there are jobs which can be done by electric motors.

The simple motor which is used for demonstration purposes in the laboratory has only two poles in the field magnet and two in the rotor or armature. Although this motor runs, it is not efficient. Because there is too much space between the poles of the field and armature magnets, magnetic force is lost. The two poles are not sufficient to supply an even flow of energy.

A commercial motor usually has a number of divisions in the armature or rotor and a number of coils in the field magnet. The diagram on the opposite page shows more nearly the appearance of a true electric motor. You will note that the field magnets are curved closely around the armature. The armature is divided into many segments.

What are some uses of electric motors? The electric motor has revolutionized housekeeping and industry. The motor used in the home is quiet, small, and strong. It can be moved from one place to another, for its only connection is the flexible insulated cord. It produces no smoke or poisonous gases. If it is properly constructed, there is little danger of fire from its use.

The electric motor runs the vacuum cleaner, the washing machine, the refrigerator, the sewing machine, the food mixer, the electric fan, the hair drier, the clock, and many other common machines. The oil burner has a fan operated by electricity. Many stokers have motor-operated coal feeders and fans to provide draft. Practically all ventilation systems are driven by electric motors.



The rotor is made up of many turns of wire. They are connected to the commutator in such a way that the north and south poles are always located halfway around from the poles of the field magnets.

In industry the uses for motors are almost countless. The electric drill, saw, and planer are used in house construction. Lathes, band saws, and drills are used in machine shops. Buffers and polishers are almost always driven by electric motors. Factory sewing machines and laundry machines are motor driven. The electric motor is the most common source of power in industry.

Electric motors are used in many ways in transportation. One type, operated by current from storage batteries, is used on warehouse platforms, in mines, and in light delivery trucks. Another type of motor is used on streetcars and electric trains which have overhead trolleys.

DEMONSTRATION. HOW DOES THE ELECTRIC MOTOR WORK?

What to use: St. Louis or other simple motor, two dry cells, wire.

What to do: Set up the motor with the permanent magnets in place, one north and one south pole producing a magnetic field. Run current from the two cells in series through the binding posts of the rotor. Reverse the wires from the cells to the binding posts.

Remove the permanent magnets, and replace them with the electromagnet. Connect the rotor and field magnets in parallel.

Remove the wires. Connect the right-hand post of the armature with the left-hand post of the field magnets. Connect the remaining posts to the cells, producing a series connection.

What was observed: Which method of operating the motor seems to produce best results?

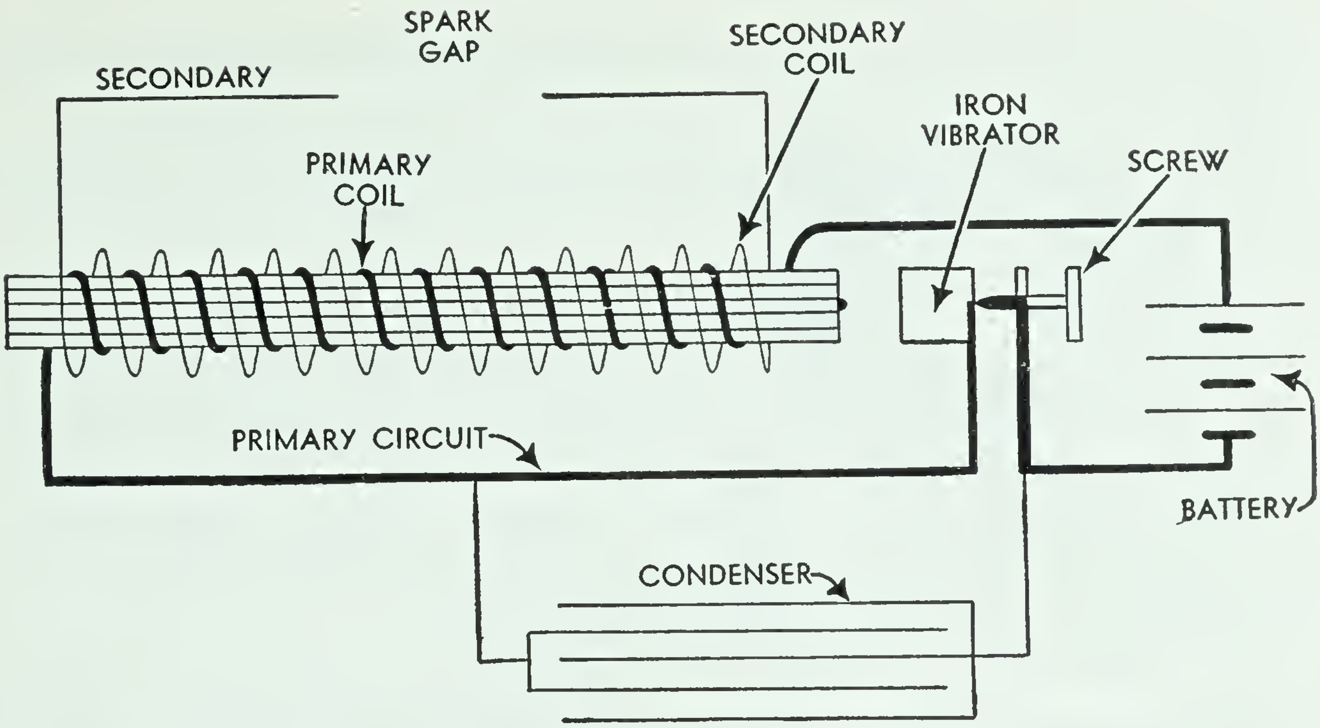
What was learned: State the principles which explain the operation of the electric motor.

Exercise. *Complete the following sentences:* The doorbell operates because the —1— attracts the armature and breaks the —2—. When the circuit is broken, the spring pulls the armature back into place, closing the —3—. The principle of the motor is that like poles —4—, and unlike poles —5—. There are two sets of poles: one on the —6— and the other on the —7—. Current is led into the armature through the —8—, which are in contact with the —9— of a direct current motor or the —10— of the alternating current motor.

Science activity. Make a simple electric buzzer. You may either design your own, or find plans in magazines of simple mechanics.

10. How is the strength of currents changed?

You know that from the same power line we take current which is used to operate electric stoves, charge batteries, light the house, and ring the doorbell. It is apparent that a single type of current is not adapted to do all these things well. How is current changed for various uses?



Whenever the current is turned on or shut off in the primary circuit, the magnetic field moves through the secondary circuit and produces a current there.

What is the induction coil? The induction coil provides current for the neon lamp, produces the spark in a gas engine, and increases the voltage of current which flows through telephone wires.

The induction coil is a rather simple device. It consists of a central or primary coil wound around a core of soft iron, a circuit breaker like that of the doorbell, and a secondary coil outside the primary wound with many turns of fine wire. The secondary coil looks almost like a large spool of thread. There is also a condenser which increases the strength of the charges of electricity in the secondary coil.

In operation a current flows through the primary coil, and the core becomes an electromagnet. The electromagnet in the diagram above attracts the iron vibrator which breaks the circuit at the screw point. The vibrator is on a spring, which pulls the weight back as soon as the electromagnet loses its power. This closes the circuit. The purpose of the primary coil is to induce a current in the secondary coil.

As you know, when a magnetic field cuts a conductor, a voltage is generated. Each time a current flows through a primary, a magnetic field leaps out through the secondary. When the current is shut off in the primary, the magnetic field leaps back to the coil. Thus a voltage is generated in

the secondary each time the current is turned on and shut off in the primary.

The condenser stores electrons for a fraction of a second before they surge through the coil. It acts to increase the power of the coil.

The change of voltage depends upon the number of turns of wire in the secondary and in the primary coils. If the primary coil has 200 turns of wire and the secondary coil has 500,000, the voltage is increased 2500 times. ($500{,}000 \div 200 = 2500$). A 6-volt current is increased by such a coil to 15,000 volts. ($6 \times 2500 = 15{,}000$). This is the approximate change in voltage that is used in automobile coils.

An induction coil does not increase the amount of energy in a current. In fact it decreases it, for some energy is lost as heat in the coils.

Power is measured in watts, which equal volts times amperes. If the voltage is increased 2500 times, the number of amperes is decreased by an equal amount. High-voltage currents from coils have low amperage—that is, they have little heating effect.

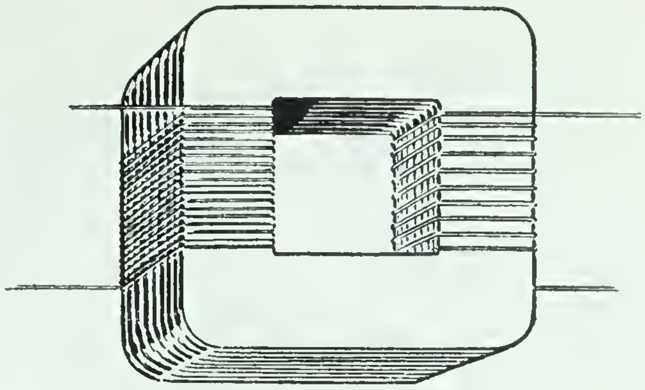
How does the transformer work? The transformer is even simpler than the induction coil. It consists of the primary coil, a secondary coil, and a ring of iron built up in layers, on which both coils are wound. Often the whole transformer is surrounded with metal strips to carry away heat and is sealed in oil inside a metal case.

The simple transformer is shown in the diagram on the opposite page. The current used in a transformer is always alternating, making a circuit breaker unnecessary. That is, the current is turned on and off each time it changes direction. The magnetic field surges around the ring shaped core from the primary coil to the secondary coil. The voltage is induced as the magnetic field cuts the secondary coil.

The change in voltage is in proportion to the number of turns of wire on the two coils. That is, the higher voltage is generated in the coil having the larger number of turns of wire.

A transformer may increase or decrease the voltage. If the voltage is increased, the number of amperes is decreased. If voltage is decreased, the number of amperes is increased.

The amount of power in watts is unchanged except for the small amount of power lost as heat in the windings and iron core.



A transformer consists essentially of two coils wrapped around a ring of soft iron. The iron core is made up of several layers of sheet metal.

The uses of transformers are many. The current that is generated at a powerhouse may be distributed to a point 10 or 15 miles away. To avoid heat losses, the voltage is kept high, 11,000 volts being a rather common voltage for this distance. It is impossible to use a current of this voltage in the house. There are substations where the voltage is reduced, perhaps to 2200 volts. From the substation the current is carried into a transformer near the house where it is to be used and reduced to 110 volts.

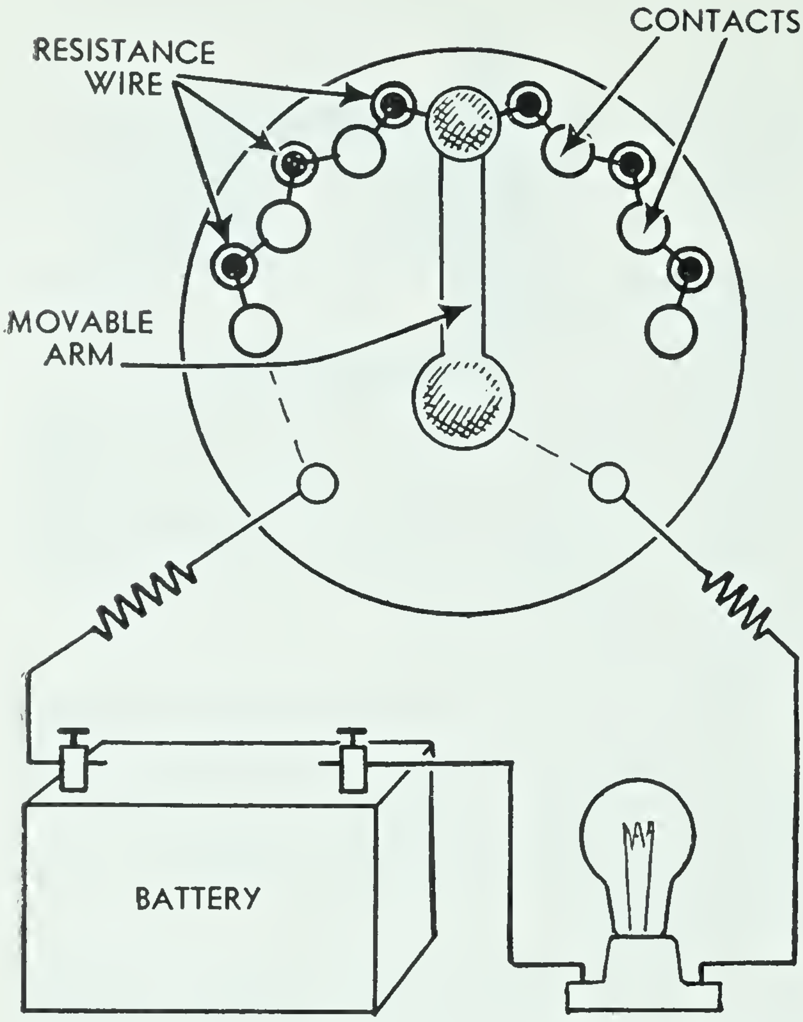
To ring a doorbell or to run an electric train, the current is further reduced to about 6 volts. To prevent having too much current flowing through a transformer, the coils are so arranged that they resist the flow of current through the primary, letting only as much through as is needed.

Transformers are used to reduce the voltage of currents for welding and to brighten or dim lights in theaters.

What are rectifiers? To change an alternating current to a direct current, devices called rectifiers [rĕk′tĭ·fī′ẽr] are used. There are a number of different types of rectifiers, working on rather different principles. Rectifiers are used in charging batteries and in radios.

How does resistance change current strength? A rheostat [rē′ō·stăt] is made up of a piece of high-resistance wire and some kind of slide which moves along the wire. Current flows through the wire to the slide. The longer the wire in the rheostat, the greater is its resistance. When the entire wire is in the circuit, the amount of resistance is high and the current is reduced. Usually the resistance wire is wound in a coil to save space.

Rheostats are convenient to use with small motors in shops to regulate their speed. Rheostats are used in arc furnaces



A rheostat is a device for changing resistance. The movable arm may be brought into contact with various points along the resistance wire. The greater the resistance, the less the current.

and lamps to prevent a short circuit when the carbon rods are brought into contact. The wire in a rheostat frequently gets very hot, for when current flows through it, the energy encounters resistance. Rheostats which get hot must be cooled or protected to avoid fire.

Demonstration. How Is Voltage Changed?

What to use: Induction coil, two dry cells, wires, screw driver, small motor, iron wire.

What to do: Connect the cells in series. Attach the binding posts of the primary coil to the dry cells. Make a contact across the posts of the secondary coil, and observe the spark. Hold a piece of paper in the spark.

Connect one post of the motor to the dry cells. To the other attach the iron wire. Slide a wire from the dry cell along the iron wire and observe the change in the rate of the motor.

What was observed: State what you observed.

What was learned: Name two devices which change the strength of a current, and state on what principle they operate.

Exercise. *Make a table by ruling your paper into four columns. Head the columns as follows:* INDUCTION COIL, TRANSFORMER, RECTIFIER, RHEOSTAT. *In the correct column write the following words:* telephone, battery charger, doorbell, resistance, spark plugs, toy train, neon lamp, welding, stage lights, substation, battery controlled motor.

Science activity. Make a model transformer. Do not attempt a working model unless you are willing to do much study.

A Review of the Unit

Electricity is a form of energy. A current is a flow of negative charges called electrons along a conductor. Static electricity is stored in nonconductors.

A voltage is generated by cutting a magnetic field with a closed conductor or by chemical changes in cells. A magnetic field surrounds every conductor carrying a current.

The rate of flow of current is measured in amperes, the pressure in volts. Resistance is measured in ohms. Amperes equal volts divided by ohms. Power in watts equals volts times amperes.

When electricity encounters resistance, heat is produced. The heating effect of electricity is used in irons and lights. Like poles or charges repel each other; unlike poles or charges attract. Work is done in motors by so winding coils that like poles constantly repel and unlike poles attract each other when current flows through the coils. Electricity is used to produce chemical changes such as those used in purifying copper and aluminum and plating spoons.

An exercise in thinking

Match the principles and related ideas, according to the directions given in the review at the end of Unit I.

List of principles

A. An electric current may be produced by chemical action.
B. Every conductor carrying a current is surrounded by a magnetic field.
C. Amperes equal volts divided by ohms.
D. Watts equal volts times amperes.
E. An electric current can produce chemical changes.
F. Like poles or charges repel each other.
G. When a conductor cuts a magnetic field, a voltage is generated which may cause a current to flow.
H. Unlike poles or charges attract each other.
I. When a current encounters resistance, heat is produced.
J. An electric current is a flow of electrons along a conductor.

List of related ideas

1. A current of 2 amperes flows when a pressure of 6 volts encounters a resistance of 3 ohms.
2. Electricity is used for plating silverware.

3. Electrons move from the negative to the positive pole along a wire.

4. Voltages are generated in dry cells which contain sal ammoniac.

5. Two similarly charged pith balls don't touch each other.

6. Copper is deposited at the negative pole in a solution.

7. The only way to get a larger current with a given resistance is to increase the voltage.

8. When a heating coil and 40-watt lamp are in series, the lamp is hotter.

9. A transformer changes the voltage and amperage of currents.

10. A current is induced in the secondary coil of an induction coil.

11. An electric motor is made up of electromagnets.

12. With a wire, a nail, and a dry cell, one can make an electromagnet.

13. Storage batteries are charged by producing lead peroxide on one plate.

14. The compass needle points north.

15. A coil with an iron core is used to lift pig iron.

16. A lemon and zinc and copper strips, properly connected, produce a current.

17. Electric lights often have a resistance of more than 200 ohms when hot.

18. A 3-volt, 4-ampere current produces the same power as a 6-volt, 2-ampere current.

19. Book plates are formed by an electroplating process.

20. A dynamo consists of coils of wire turned between magnets.

21. Watches are magnetized if carried too close to coils carrying current.

22. Electrons, which are negative charges, are attracted to positively charged plates in the photoelectric cell.

23. Lye and chlorine can be made from table salt by using a direct current.

24. With a given voltage, increasing the resistance decreases the current.

25. Fuses melt when an overload of current flows through them.

26. A toaster works because of the heating effect of electricity.

27. The only proof that a piece of iron is magnetized is to use it to repel another magnet.

28. Metal is welded where pieces join, by current flowing from one piece to another.

29. Nichrome wire is sometimes used for heating coils.

30. Lightning sometimes sets trees on fire when it strikes them.

31. A magnet thrust through a coil causes the galvanometer needle to move.

32. Currents are produced when electrons are released by chemicals in solution.

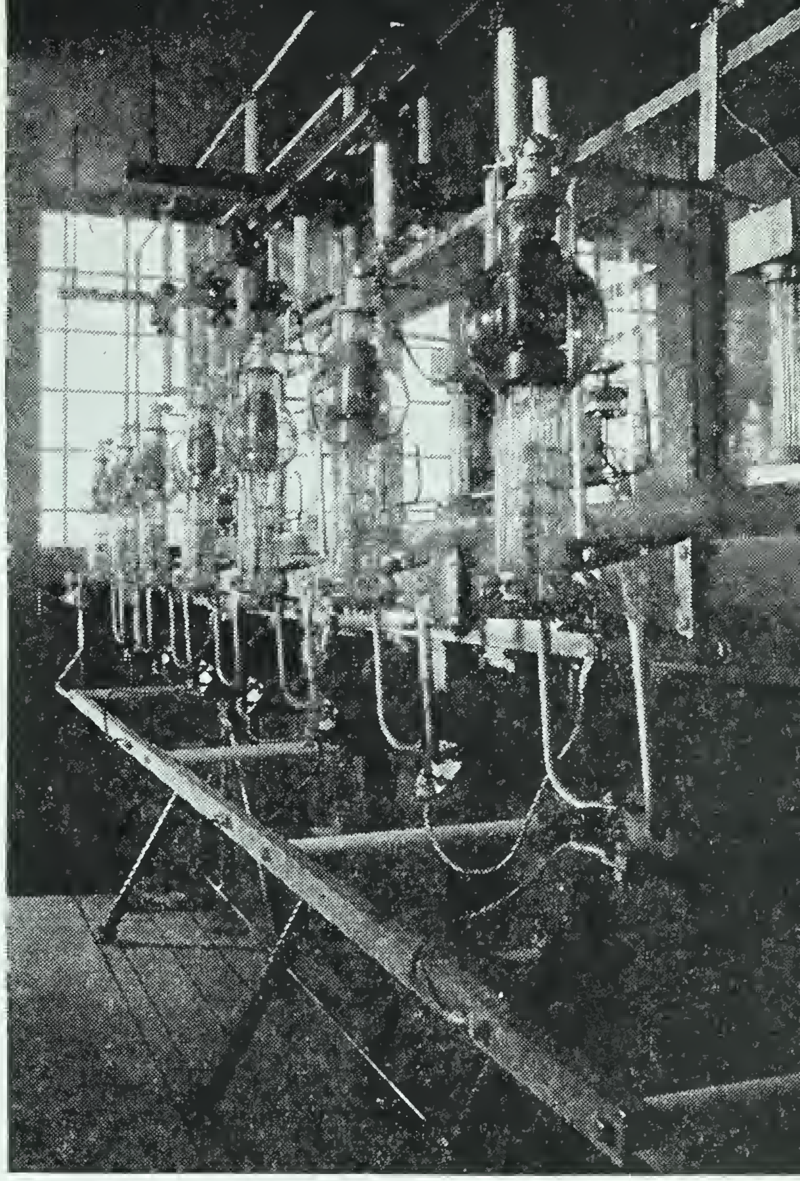
33. No more energy comes from a transformer than goes into it.

34. The rotor magnets and field magnets are wired so that like poles are caused to repel.

35. Country telephones are rung by a crank turning a coil between magnets.

36. The first currents were produced by stacks of copper and zinc strips, separated by cloths soaked in salt water.

37. A primary coil of a transformer magnetizes an iron core.



Courtesy Western Electric Company

This is the rectifier unit in a broadcast transmitter for 500 kilowatt operation. The six tubes used are 75 amperes each.

38. The iron core of a transformer carries a magnetic field to the secondary to produce a current.

39. Dry cells are used in series to overcome resistance.

40. A current results when static electricity is discharged along a conductor.

Some things to explain

1. How was electricity used in printing this book?

2. In your house find five devices used to make electric wiring safe.

3. Why do gasoline trucks have a chain dragging on the ground?

4. If you had a bar magnet with the poles unmarked, how could you find which was the north pole?

5. How can you find the cost of electricity used in your home in a month?

6. How do gasoline engines use electricity?

7. Explain the difference between Christmas-tree wiring and house-wiring.

8. Why can you not receive a shock from a dry cell?

9. Why is electricity more dangerous when you handle electrical devices with wet hands?

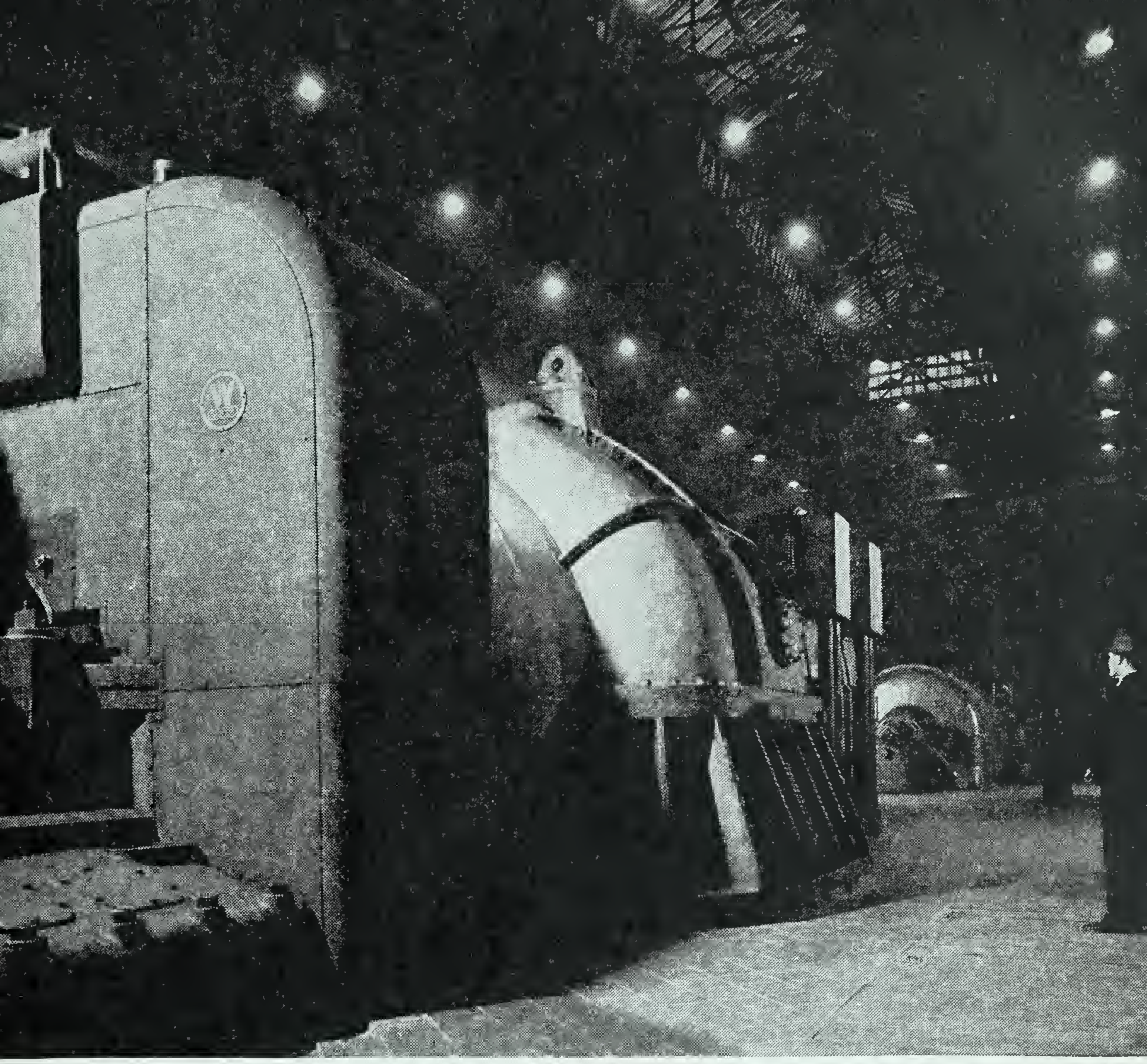
10. Write 10 rules for safety around electricity.

Some good books to read

Adams, J. H., *Harper's Electricity Book for Boys*
Book of Popular Science, Grolier Society
Collins, A. F., *The New World of Science*
Compton's Pictured Encyclopedia
Gibson, C. R., *How We Harness Electricity*
Klinefelter, L. M., *Electrical Occupations*
Lunt, J. R., *Everyday Electricity*
Meister, M., *Magnetism and Electricity*
Morgan, A. P., *The Boy Electrician* (rev. ed.)
Morgan, A. P., *Things a Boy Can Do With Electrochemistry*
Timbie, W. H., *Essentials of Electricity* (2nd ed.)
Williams, H. S., *The Story of Modern Science*
World Book Encyclopedia
Yates, R. F., *How to Make Electric Toys*

Some interesting motion pictures

Dynamic America. Westinghouse (*16 silent or sound*)
Early Experiments of Michael Faraday. General Electric Company (*16 sound*)
Electrostatics. Erpi (*16 sound*)
Electrons. Erpi (*16 sound*)
Principles of Current Generation. Y.M.C.A. Motion Picture Bureau (*16 silent*)
Principles of Electrical Measurement. Y.M.C.A. Motion Picture Bureau (*16 silent*)
Induced Currents. Eastman (*16 silent*)
Magnetic Effects of Electricity. Eastman (*16 silent*)
Chemical Effects of Electricity. Eastman (*16 silent*)
Principles of Magnetism. Y.M.C.A. Motion Picture Bureau (*16 silent*)
Electric Power in the Southern Appalachians. Eastman (*16 silent*)



Courtesy Westinghouse Electric and Mfg. Co.

This large turbine generator turns at 1800 revolutions. It produces electricity for Pittsburgh.

Story of a Storage Battery. (2 reels). U. S. Bureau of Mines (*16 silent*)

Heat and Light from Electricity. Eastman (*16 silent*)

Some related lantern slides

Electricity. Keystone View Co.

UNIT FIVE

HOW DOES LIGHT HELP US TO KNOW THE WORLD ABOUT US?

WE ALL know that light makes seeing possible and that our sense of sight is the chief means we have of knowing what is going on around us. Without ability to use light we might be like blind fish in a cave, unable to know more than we could discover by touch, smell, and hearing. For so complex an animal as man, life without sight would be almost impossible.

We use our eyes to learn almost all that we know. We depend upon what we read, what we observe, and what we see in pictures to guide our actions and to improve and control our surroundings.

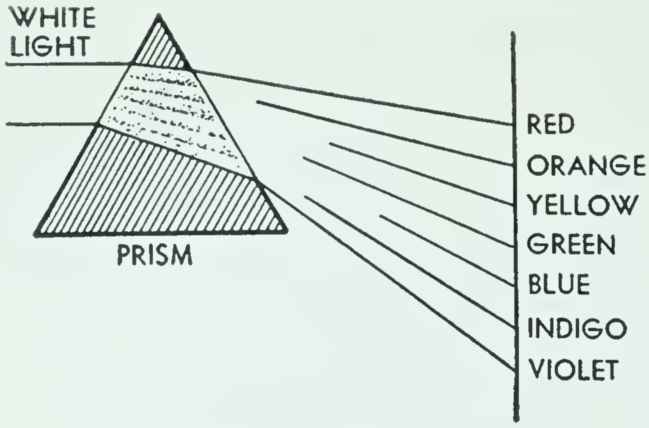
We help our eyes in many ways by controlling light. At night when the sun is gone we build fires or light lamps or use electricity to prolong the day. We use the microscope, the telescope, the spectroscope, and the camera to learn from the universe of great and small things the secrets we must know to advance our skill and knowledge.

We go to the movies to enjoy our leisure time, to dream of the life of adventure, and to escape our problems and difficulties for a short time. Taking and developing pictures is the most widespread of all hobbies.

Our health depends in many ways upon light. If we read by light that is too dim or by light that shines in our eyes, it may be necessary for us to obtain glasses to correct the damage caused by our carelessness. Our houses are too often not well arranged for good lighting conditions and, as a result, we must be very careful to obtain the best conditions possible whenever we read or study.

Many children do not assist in keeping classroom conditions favorable for good seeing. They may sit in spots of sunlight or move their chairs to face a window as they read. They may hold their books on their laps, in the shadow of a desk top. Yet it is not necessary for us to handicap ourselves by bad lighting conditions, for modern electric lights will provide safe and economical light.

Modern lights are more wonderful than the Lamp of Aladdin, for his lamp could produce only riches and power—it could not produce light that would compare with the glow of a modern 100-watt bulb.



A prism separates light into colors. A ray of white light is separated to form the colors of the spectrum.

1. What is the nature of light?

If you were asked which reflects more colors, a painting or a piece of white paper, you probably would select the painting. You would be wrong. Even the gaudiest painting absorbs more colors than it reflects. A piece of white paper does not absorb any color.

What is color? It is light that has color and not colored objects. In a completely dark room all objects are black—that is, without color. It is possible for objects to have color only as they reflect or separate light.

You have seen rainbows with their colors ranging through violet, indigo, blue, green, yellow, orange, and red. The colors of a rainbow are called the spectrum. The raindrops separate the light that passes through them into the colors of which the light is made.

Our eyes are so constructed that they contain three kinds of nerves which are sensitive to three colors: red, green, and violet. Each kind of nerve is sensitive to some extent to other colors. Some eyes are not sensitive to any colors, but are color-blind. Most color blindness results from inability to distinguish between red and green.

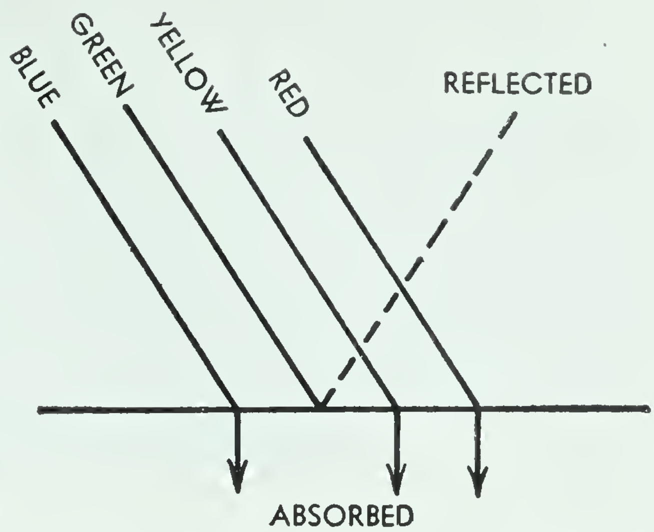
When the colors to which the eye is sensitive strike it in equal amounts, the eye sees white. Some colors which the eye sees depend upon its ability to be deceived. If a variously colored wheel is rotated rapidly, the colors seem to blend. Red and blue blend to make purple. Blue and yellow blend to make green.

An object has color because it reflects only part of the light which falls upon it. For example, a red object absorbs all colors but red and reflects only red. A blue object absorbs all colors but blue.

Why does light have color? Let us produce the spectrum on the wall of the science room by shining a beam of light

through a glass prism. The prism bends light rays and separates the colors which make up white light. The light falls in colored bands. The violet light is bent most, the blue next, green next, and so on. Red is bent least.

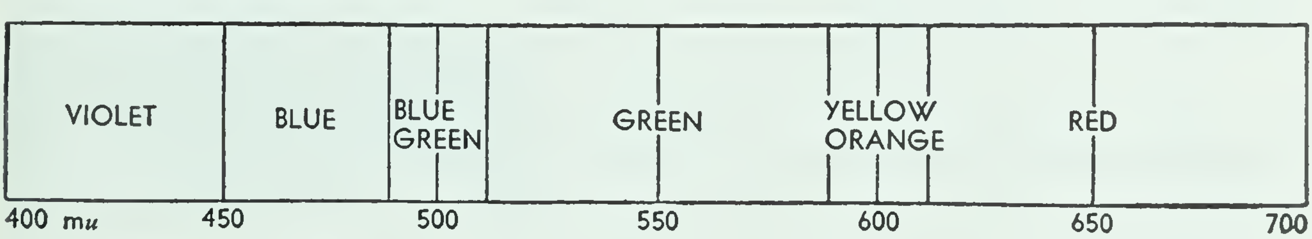
Light is a form of radiant energy which travels in waves. Color really depends upon the wave length of light. The average distance between light waves is only 1/50,000 of an inch. There is a unit for measuring the wave length of light called the millimicron. Violet light waves are about 400 units in length. Light waves between 400 and 500 units in length look blue. Light with a wave length of between 500 and 600 units looks blue-green, green, or yellow-green. Light waves between 600 and 700 units in length are orange-red or red.



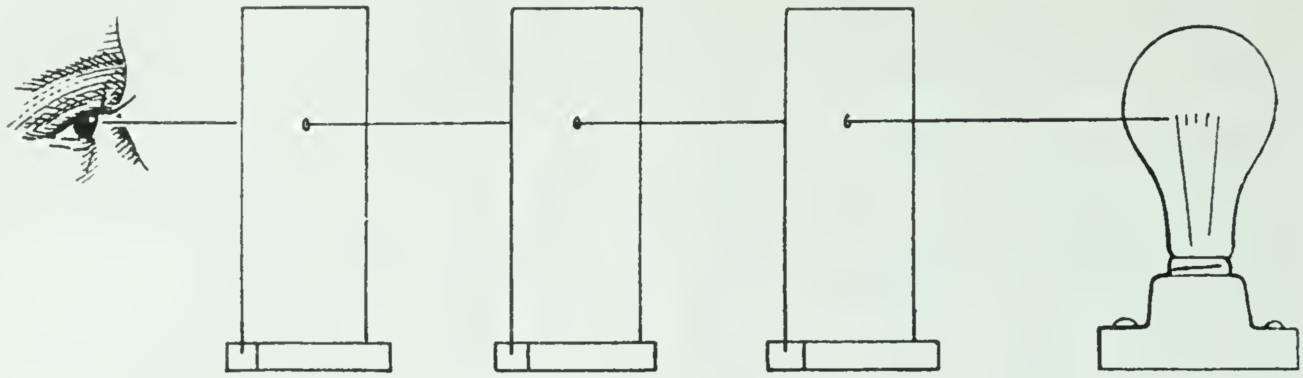
White light is made up of blended colored light. Some surfaces absorb certain rays and reflect the others. The color of the surface is the color of the light reflected. What color of surface is shown in the diagram?

The waves just shorter than 400 units in length are called ultraviolet energy, while those just longer than 700 units in length are called infrared energy. Neither is visible. Both come from the sun, just as light does, and if our eyes were more sensitive we could see by these types of energy.

How do light waves travel? Light waves travel through space, apparently without being carried by any material. We know that water waves travel in water, sound waves in air, and waves of rope along the rope. It has not been proved that light travels in anything. Light is one of the electromagnetic radiations.



The color of light is determined by its wave length. This diagram shows the relation between color and wave length. The figures represent millimicrons, the measurement for light waves.



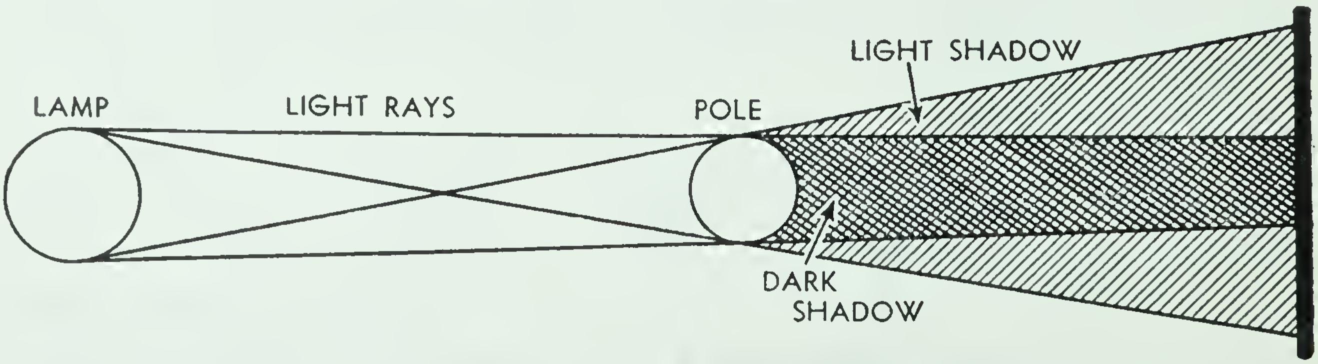
Light travels in straight lines. It is possible to see the lamp only when the holes in the cards are in a straight line.

Light travels at a speed of more than 186,000 miles a second. That is, the light from the sun, which is 93,000,000 miles away, comes to us in about eight minutes. Light from the stars travels for years before it reaches us.

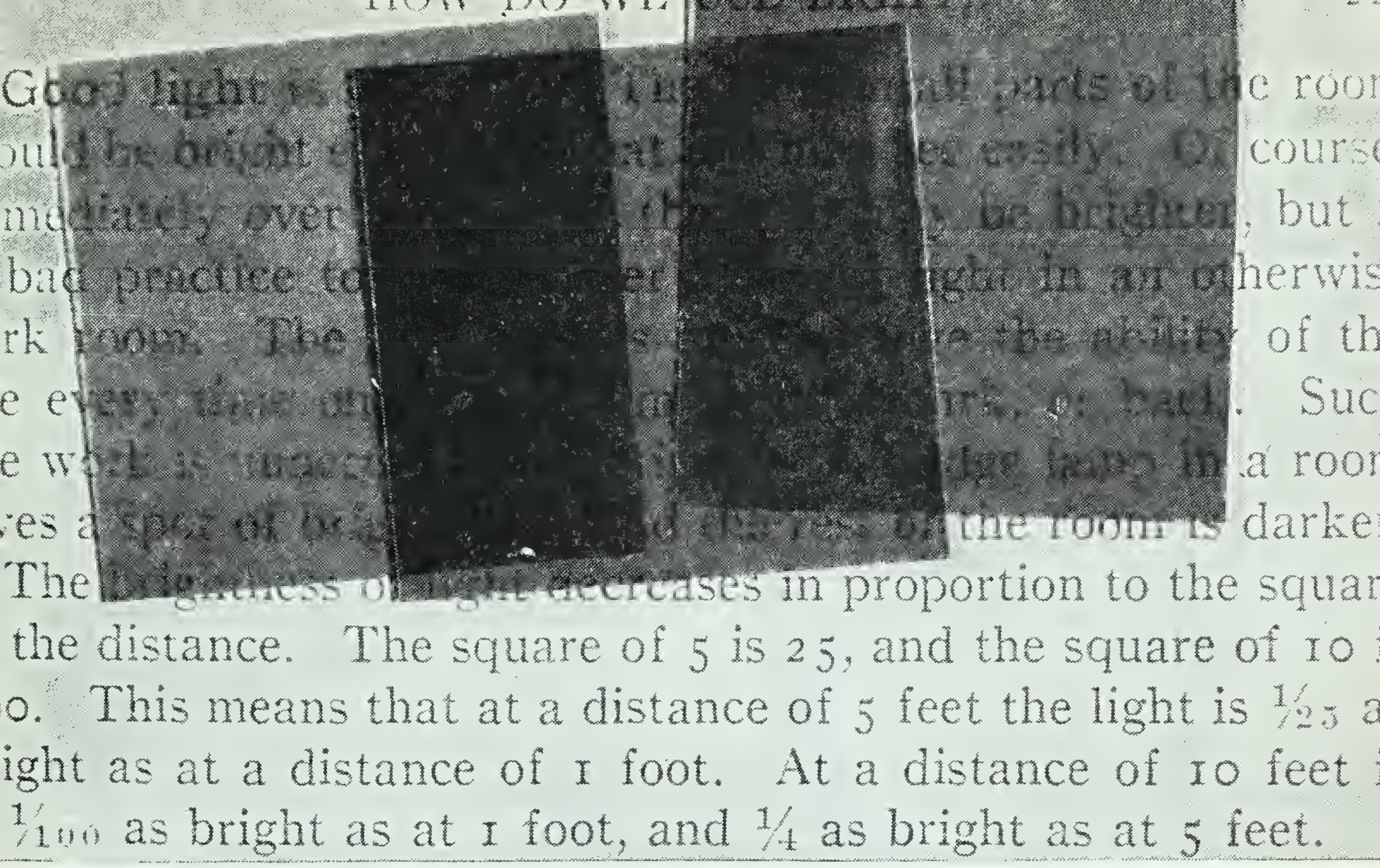
Light waves move in straight lines. If you put three cards in a row, with holes in them arranged in a straight line, a light can be made to shine through all three holes.

Because light travels in straight lines, shadows are formed where light is shut off by some opaque [ō·pāk′] object. If the light comes from a point or in parallel rays from the sun, the edges of the object are sharp and black. If the light comes from a broad surface, such as a kerosene lamp flame or a neon sign, the shadow is blurred. Directly behind the object there is a dark shadow which is called the *umbra*. The hazy, lighter shadow area in which the light is not entirely shut off is called the *penumbra*. Shadows are rarely completely black because dust in the air scatters light. Light may also be reflected from near-by objects into the shadow.

Does light pass through all substances? Materials vary greatly in their ability to transmit light. Opaque substances,



This is the top view of the shadow of a pole as produced by a street lamp. Why is there a dim shadow cast by the pole?

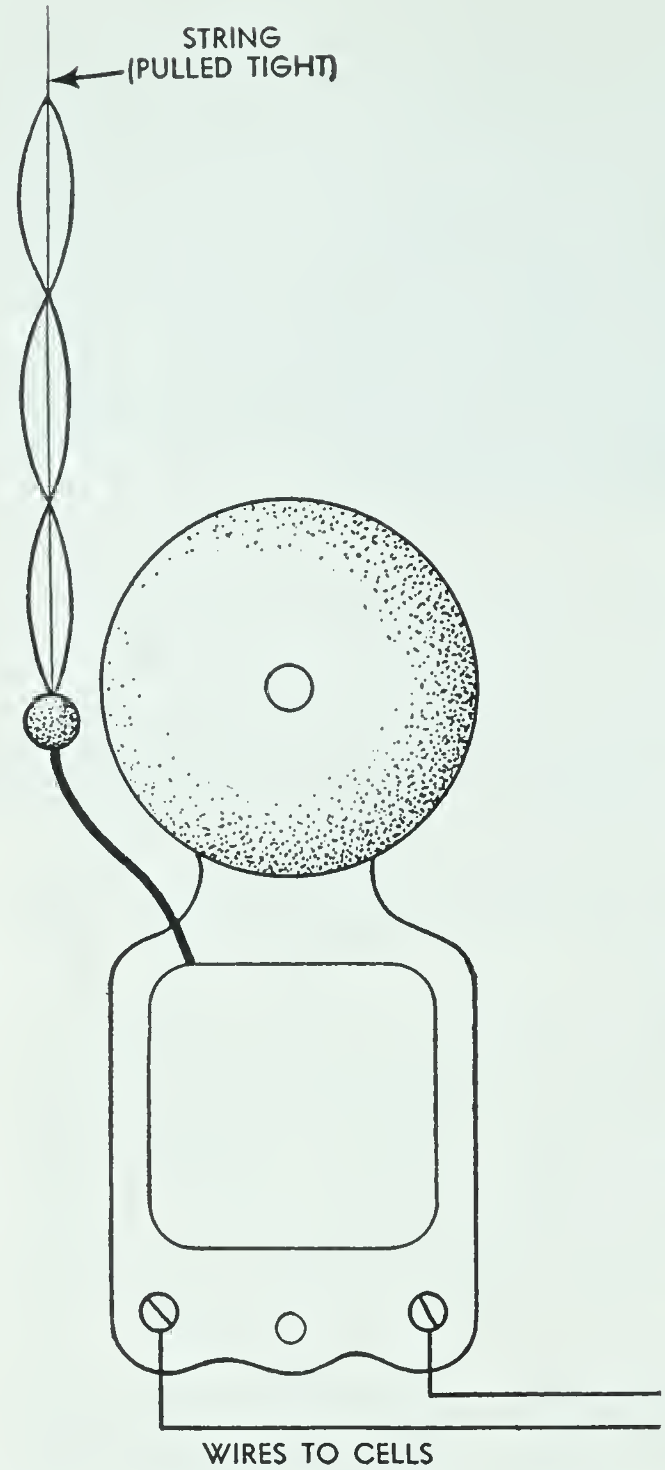


Three pieces of polaroid are shown lying on a printed page. The first and second pieces are "crossed." The second and third pieces lie so that their crystals are nearly parallel. Does polaroid absorb light?

such as wood, stone, metal, and leather, do not transmit a visible amount of light. Translucent materials transmit some light but diffuse it. One cannot see clearly through such translucent materials as paraffin and frosted glass. Transparent materials transmit enough light that we can see through them. Glass, water, air, and quartz crystals are transparent.

Some materials may be transparent and yet absorb much light. Red cellophane absorbs all the colors from light but red. If we look at a blue dress through red cellophane, the dress looks black. Ordinary window glass permits visible light to pass through but absorbs ultraviolet energy. Sunshine which enters through the window cannot sunburn us or help to develop resistance to rickets. One type of glass absorbs infrared rays—the heat rays—and helps to keep the house warm in winter and cool in summer.

Materials not only absorb light in different amounts and absorb different colors, but one material—polaroid—also absorbs light waves that travel in certain directions. The illustration used to show how light travels was a comparison of light waves with waves in a rope. If you put the rope through



This apparatus may be used to produce waves of various lengths. Changing the tension upon the string changes the length of the waves.

a picket fence, you can shake it so that up-and-down waves go through the fence, but the sidewise waves are stopped by the pickets. Similarly, polaroid stops all waves except those which lie in the direction of the crystals of which it is made.

If you cross two pieces of polaroid, they shut out almost all light. That is, if you put one piece of polaroid over a headlight and another at right angles to it in a windshield, the headlight is seen as a dim glow instead of a brilliant glare through the windshield. Yet all objects illuminated by the headlight look perfectly normal because the diffused polarized light is remixed. Polaroid absorbs more than half the light that strikes it, and if it is used in headlights we need brighter than ordinary lights.

Polaroid is used to judge flaws in glass, to produce color effects, to study chemical composition of materials, to make better photographs, to make three-dimension movies, and to locate strains in models of machines.

Demonstration. What Is the Nature of Light?

What to use: Doorbell, dry cell, string, prism, projector or sunlight, cardboard, polaroid, if available.

What to do: Set up the bell apparatus as shown in the diagram. Bend the clapper so that it makes no sound, and complete the

circuit. The length of the waves may be regulated by pulling on the string. Try to measure the wave length of the waves. See if you can stop the waves by putting the string through a slit in a piece of cardboard.

In a darkened room set up the prism in a beam of light, and turn it until a spectrum falls upon the wall or ceiling. Study the spectrum.

If polaroid is available, follow the directions which come with the apparatus.

What was observed: Describe what was done.

What was learned: What is meant by wave length? What is the source of color? How does polarized light differ from ordinary light?

Filmstrip: Light. Visual Science.

Exercise. *Complete the following sentences:* Light is a form of —1— energy which travels —2— miles a second. It moves in —3— lines with a —4— motion. Light passes freely through —5— substances; it is scattered but passes through —6— substances, and does not pass through —7— substances. Color of light depends upon its —8—. —9— energy, which causes sunburn, is invisible. All colors are reflected equally by —10— and absorbed by —11— objects. White light is separated into colors by a —12—.

Science activities. 1) Obtain colored cellophane, and view various colored objects through it. Make a chart of your results.

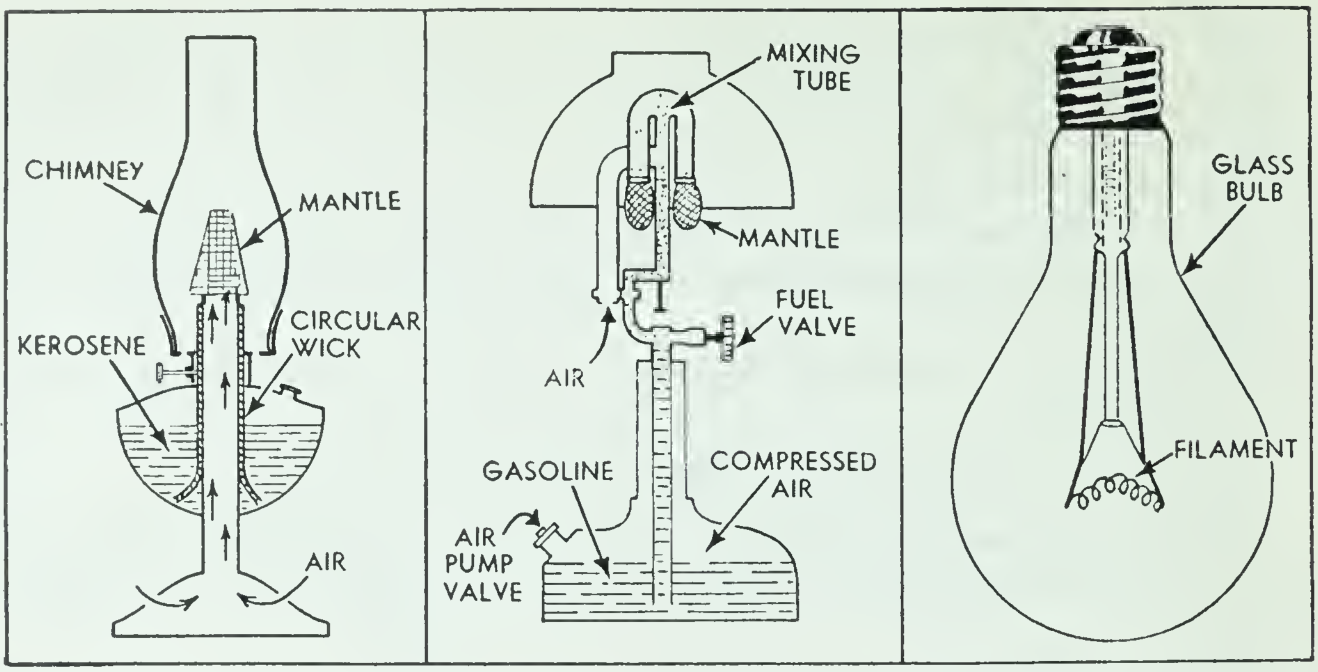
2) Put a colored cellophane cover over an electric lamp, being careful that it does not come into contact with the hot bulb and start burning. Try to identify the color of objects in the room. This experiment must be done at night.

3) Make a chart of optical illusions.

2. How do we produce light artificially?

One of the first advantages man gained over the wild animals was his mastery of fire and control of light. Because man learned to use fire, and found that the light it gave lengthened his day, he changed many of his habits of living. Today a day is actually 24 hours long and not merely the time from sunrise to sunset.

What are different types of lights? The first lamp probably was a wick floating in a crude bowl of oil. The in-



Each of these pieces of lighting equipment depends upon incandescence to produce light. What produces the heat in each case?

vention of the candle made it possible to carry the light more safely and store the fuel more readily than was possible with a lamp.

The first real improvement in lamps came with the use of kerosene as a fuel and the invention of the flat-wick kerosene lamp with a chimney to protect the flame. More recently the wick was made round, and air was admitted from a pipe through the center of the lamp to produce a blue flame. Then a mantle was added. By using a mantle heated to incandescence [ĭn′kăn·dĕs′ĕns—hot enough to give off light], a clear light is produced at low cost.

In the gasoline lamp the gasoline is forced by compressed air from the fuel tank through a carburetor, where it is mixed with air and blown into a burner which works almost like a blowtorch. The hot flame heats a mantle which gives off light. Gasoline lamps and lanterns are extensively used on farms, in camps, and for outdoor life. The gasoline mantle lamp is equal in amount and quality of light to many electric lights. It is not as safe or convenient.

What is the incandescent electric light? Edison invented the first successful electric light in 1879. It consisted of a carbon filament inside a globe from which the air was pumped. This lamp, with minor improvements in the filament, was used for several years. Then it was found that the metallic element tungsten, on account of its high melting

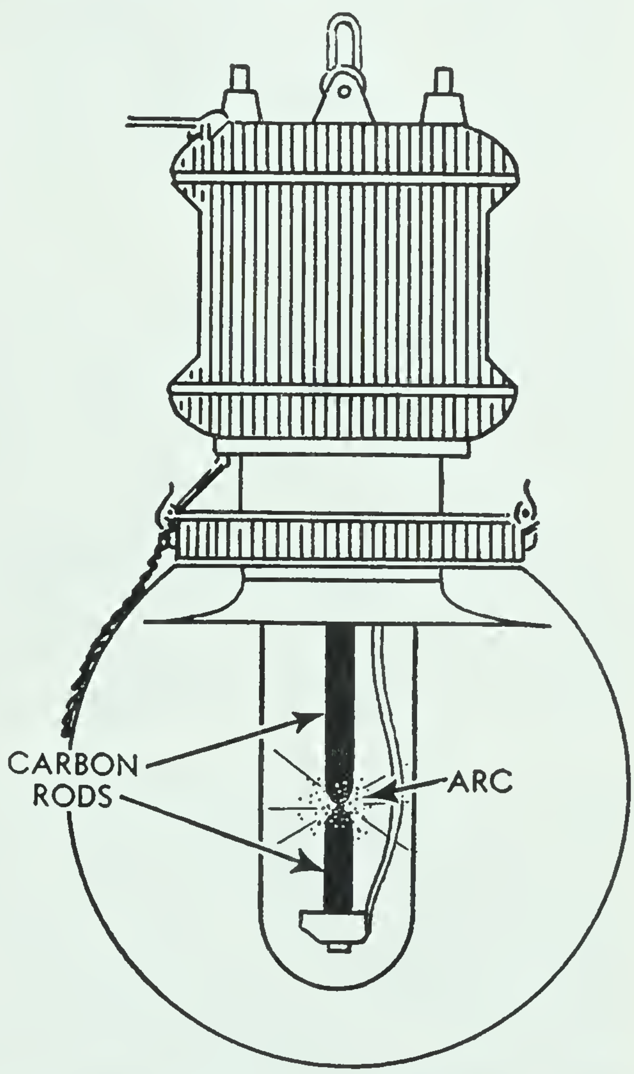
point and its resistance to oxidation, was suitable for filaments. Later the vacuum was replaced in larger bulbs with nitrogen, argon, or other inert gases. These gases improved the efficiency of the lamp by reducing the speed of evaporation of the filament.

All incandescent electric lamps depend for illumination upon heating a wire of high resistance by the current flowing through it. The larger lamps use more current and give off more light than do the smaller lamps.

The incandescent lamp of today is about 20 times more efficient than the first commercial lamp, put on the market by Edison, and now provides the best all-around illumination available at a moderate cost. One should buy an inside-frosted, gas-filled, tungsten filament lamp, manufactured by a firm of good reputation. Only white lights should be used for illumination because colored lights are inefficient and tiring to the eyes.

Lamps should be burned on exactly the voltage for which they are made. A 110-volt bulb on a 120-volt circuit gives bright light but burns out in about half the time that it should last. In general, it has been found that the larger lamp bulbs are more efficient than the smaller ones.

What is an arc light? Sir Humphrey Davey demonstrated the first arc light in 1809, using current from a huge battery. The arc light is still used in searchlights and projectors in large motion picture theaters because it produces a brilliant point of light.



The arc light is still in use for street-lighting in some cities. It is of interest today because it was an early source of brilliant light. The arc is now used in some projectors and furnaces.

An arc lamp has in it two carbon rods which become heated when brought together by a machine built into the lamp. The rods give off vapor which is heated to incandescence by the current. The rods are then moved apart and the current flows through the vapor.

How are gas lights used? Near fields of natural gas, gas is still used to heat mantles to produce light. Gas lights are fairly efficient but are dangerous because of the poisonous nature of all illuminating gases. They also present a fire hazard, just as kerosene and gasoline lamps do. The use of gas for light was once common in almost all large cities.

Acetylene gas made from calcium carbide and water is used in some miners' lamps and in bicycle lights. Acetylene is also used in welding.

How do neon type lamps work? The commonest gas-type lamp made without a filament is the neon lamp. Wires lead into each end of the tube. The current is discharged through the gas which is sealed into the tube under very low pressure. Most neon lamps are operated from transformers which increase the voltage of the current. Neon lamps are used in signs and for decoration. Neon gas gives an orange color, mercury vapor produces blue, and helium a pale yellow-white light. By coloring the glass tubes, other colors are obtained.

The light is produced in all neon-type lamps by the action of electrons on the molecules of the gas.

How do fluorescent lamps work? The fluorescent lamp is the most promising improvement in lighting since the invention of Edison's lamp. It is a glass tube filled with gas under low pressure. These lamps are somewhat more than an inch in diameter, and range in length from 14 to 48 inches. The tube contains mercury vapor which is caused to glow by the current. Invisible ultraviolet energy is given off by the glowing mercury. The ultraviolet energy is absorbed in a chemical paint on the inside of the tube. The energy of ultraviolet light is then given off, but at an increased wave length, and visible light is produced. Different chemicals inside the tubes produce different colors: green, yellow, blue, red, pink, daylight, or white.

Fluorescent lamps give a soft, even light. The daylight color is especially pleasing to the eye. A 15-watt fluorescent

lamp gives as much light as a 40-watt Mazda lamp. These lamps require different circuits than do ordinary Mazdas and are somewhat expensive to install for home use.

What are the two photographic lamps? There are two types of photographic lamps: the photoflood and the photoflash. The photoflood is a Mazda lamp with a short, thick filament. It uses a large amount of current, and gives an intensely bright light. Photofloods burn out in two to ten hours. The photoflash is made of thin wires or sheets of aluminum or other metal enclosed in a bulb of oxygen. The current sets the metal on fire, and it burns with a brilliant flame lasting about one-fiftieth of a second. Both types of photographic lamps give a bluer light than is ordinarily produced by artificial lights.

Courtesy Westinghouse Electric and Mfg. Co.

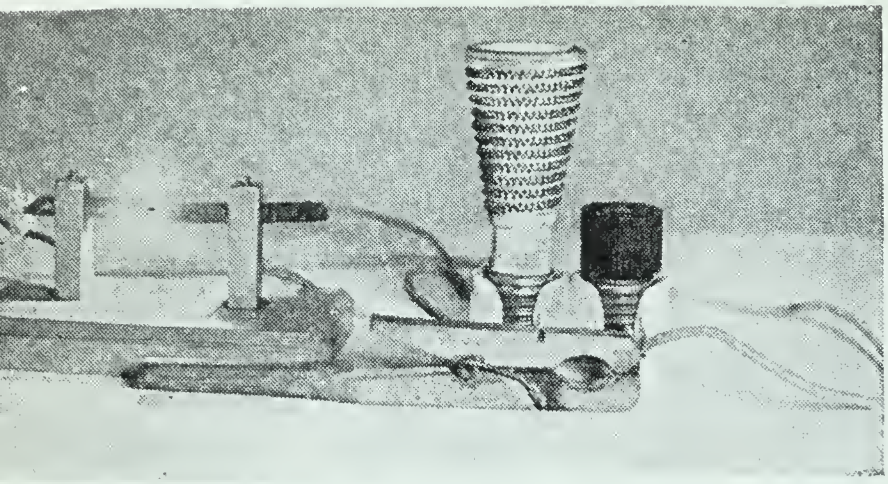
The sterilamp is a long tube filled with mercury vapor which gives off ultraviolet rays. These rays are particularly deadly to fungous plants which cause food to decay. Their use decreases spoilage of meat.

How do radiant energy lamps work? Infrared lamps are used for treatment of certain diseases and muscular pains which are benefited by heat. They are essentially carbon-filament lamps, which are inefficient light producers and only moderately efficient heaters.

The ultraviolet, or mercury vapor, lamp is used to treat some kinds of skin infections and to build up resistance to rickets in babies. Ultraviolet energy is used in restaurants to kill germs on glasses and dishes, which are usually put directly under the lamps. Such lamps are enclosed to protect the eyes of the restaurant workers who may be near.

Demonstration. How Is Artificial Light Produced?

What to use: Heating coil in socket, carbon rods, various electric lamps, spring clothespin, induction coil, fluorescent Geisler tube, dry cells.



This picture shows one way to arrange carbon rods to make an arc lamp. Why is the coil used in series? Why is a wooden clamp used to move the carbon rods?

What to do: Connect the carbon rods, as shown in the illustration, in series with the heating coil in the lighting circuit. (*Be sure the connection is in series.*) Using a spring clothespin for insulation, move one of the carbon rods so that it touches the other, and slowly move it away. Observe the resulting arc.

Set up various kinds of lamp bulbs side by side in the ordinary circuit, and observe them to see if you can detect differences in their brightness. Compare old and new bulbs.

Send current through the fluorescent tube from the induction coil.

What was observed: Report on each step of the experiment what you observed.

What was learned: What are the two principles of producing artificial light?

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* incandescent, carbon, nitrogen and argon, filament, resistance, tungsten, neon, mercury, fluorescent, photoflash, oxygen, ultraviolet, wave length.

Science activity. Make an arc lamp. Use flashlight battery carbons for rods. Connect your arc in series with the electric iron. (*Be careful not to touch the carbons with your hands!*)

3. How do we use artificial light?

The correct use of artificial light is an important factor in health and efficiency. Modern ways of living make many demands upon our eyesight that primitive man did not encounter. Many common tasks require constant, close use of the eyes.

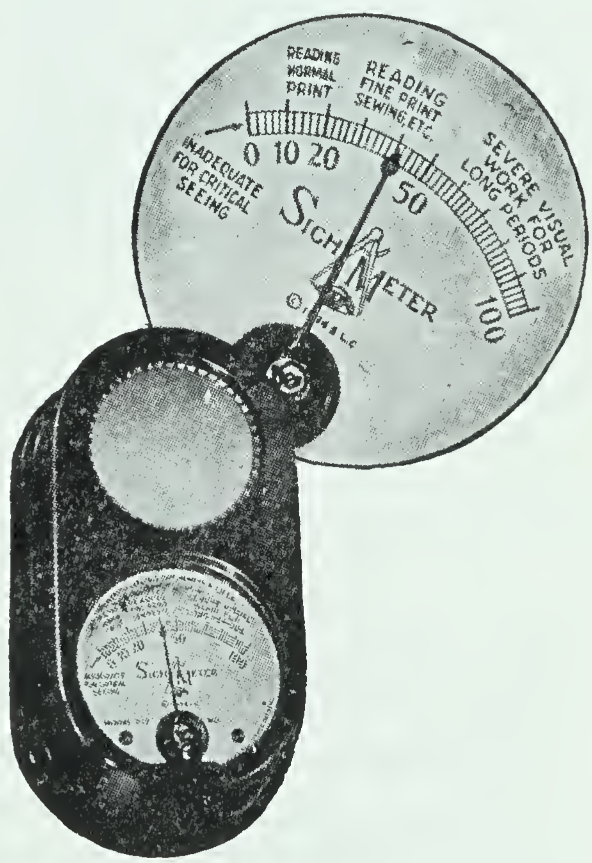
Good lighting must meet three major requirements. It must be bright to provide enough light for the work to be done. It must not glare. It must be fairly uniform in different parts of the room.

How bright should light be for safe use? The standard unit of brightness of light is the foot-candle, which is the amount of light produced by a certain standard candle at a distance of one foot.

Practically, brightness of light is measured by use of a sight meter, which consists of a photoelectric cell upon which the light falls and a galvanometer which measures the current from the cell. The brighter the light falling on the cell, the greater the amount of current produced. The dial is marked to be read in foot-candles.

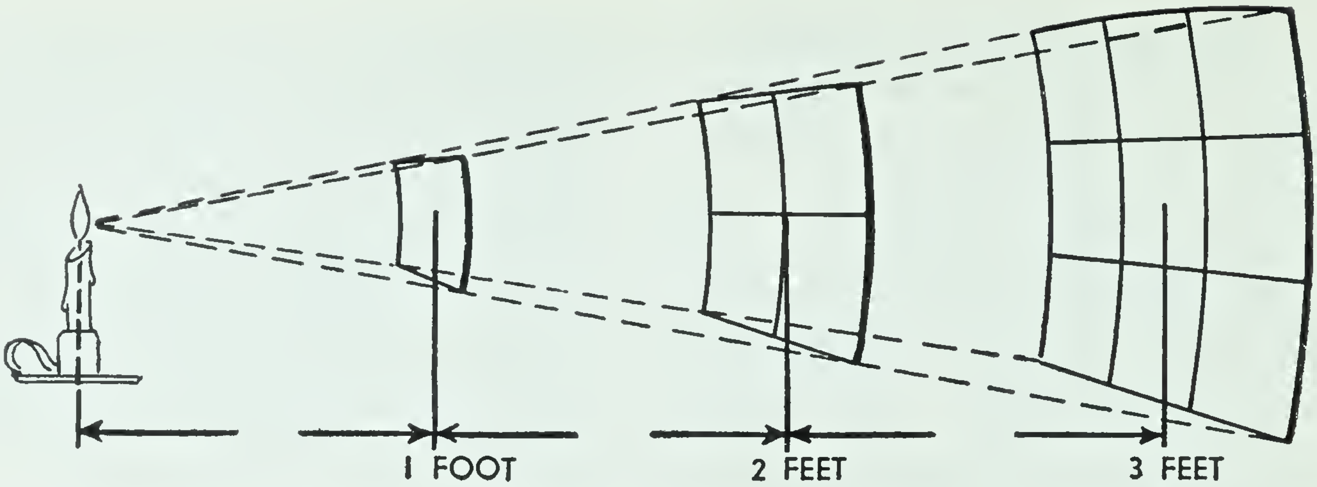
The brightness of the sun at noon on a midsummer day may be as great as 10,000 foot-candles. The brightness of light in the shade on a summer day is about 1000 foot-candles. Moonlight has a brightness of only .02 foot-candles. The brightness of light on a book three feet from a 60-watt Mazda lamp is 15 to 20 foot-candles. Brightness of light for reading should be more than 25 foot-candles. For general illumination and for housework, 5 foot-candles is sufficient.

The brightness of light depends not only upon the source of the light but upon the distance from the light. If the brightness one foot from a candle is one foot-candle, the brightness two feet from it is only one-fourth foot-candle. The same light falling upon a surface three feet away is only one-ninth as bright as at a distance of one foot. The law is stated thus: The intensity of light varies inversely in proportion to the square of the distance from the source.



The sight meter measures the brightness of light in foot-candles. The gray circle is part of a photoelectric cell.

What is glare? Glare results when any light shines directly into the eyes. The light may come from an uncovered lamp, or it may be reflected from a mirror or a varnished table top. When a



The same amount of light that falls upon a surface at one foot from a candle covers a surface nine times as large at a distance of three feet.

glaring light shines into the eye, the pupil, or opening of the eye, closes up, and shuts out the dimmer, reflected light by which we see objects around us. The brighter the glaring light, the less we can see of ordinary objects. Glare is tiring to the eyes.

Why should light be uniform? When we look at a part of the room which is very bright, the pupils of our eyes become smaller. If we then look into a part of the room that is dark, the pupils must become larger to enable us to see. Constant changing of the size of the pupil of the eye is tiring to the eye muscles and causes eyestrain.

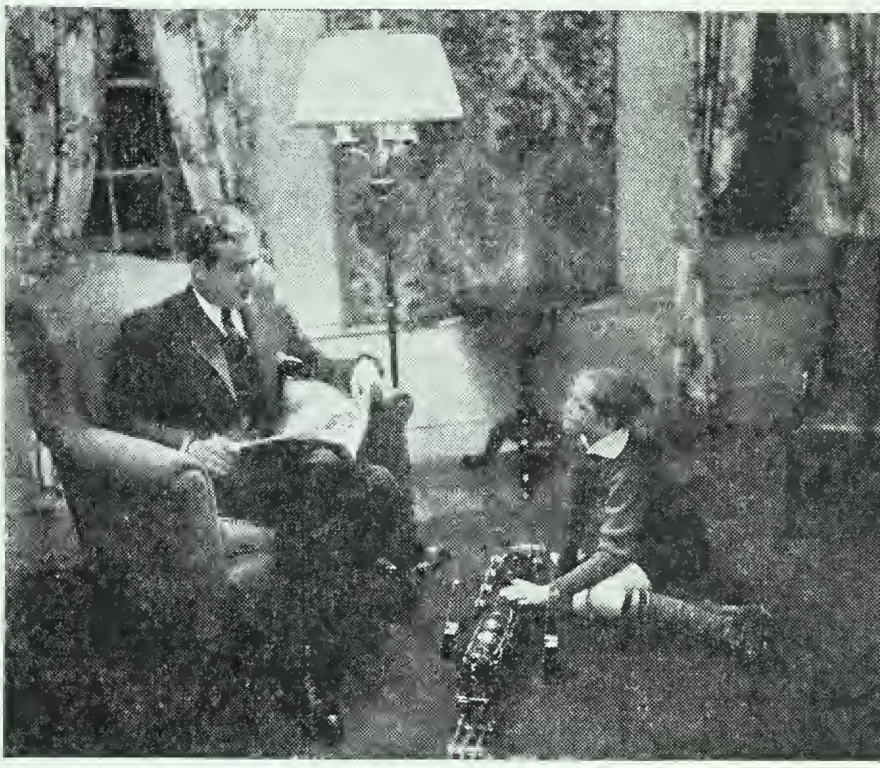
How can lamps best be used? Probably the poorest light in general use is the light from a kerosene oil lamp. It produces a light too dim for reading or sewing comfortably, even at a distance of a few inches. The light is glaring, and the room is hardly lighted at all by a kerosene lamp.

Gasoline and kerosene mantle lamps are usually provided with a shade of opal glass which scatters or diffuses the light to reduce glare. These lamps provide enough light for ordinary household needs. The usual practice of placing any lamp upon a low table is not desirable, for the light should come from above instead of from directly in the line of vision.

Why do we use electric floor lamps? The worst methods of using an electric lamp are to hang it from a cord in the center of the room or to put it in an exposed wall fixture. The old-fashioned bridge lamp, with its heavy, ornamental shade, its small lamp, and its small circle of bright light, is almost as bad.

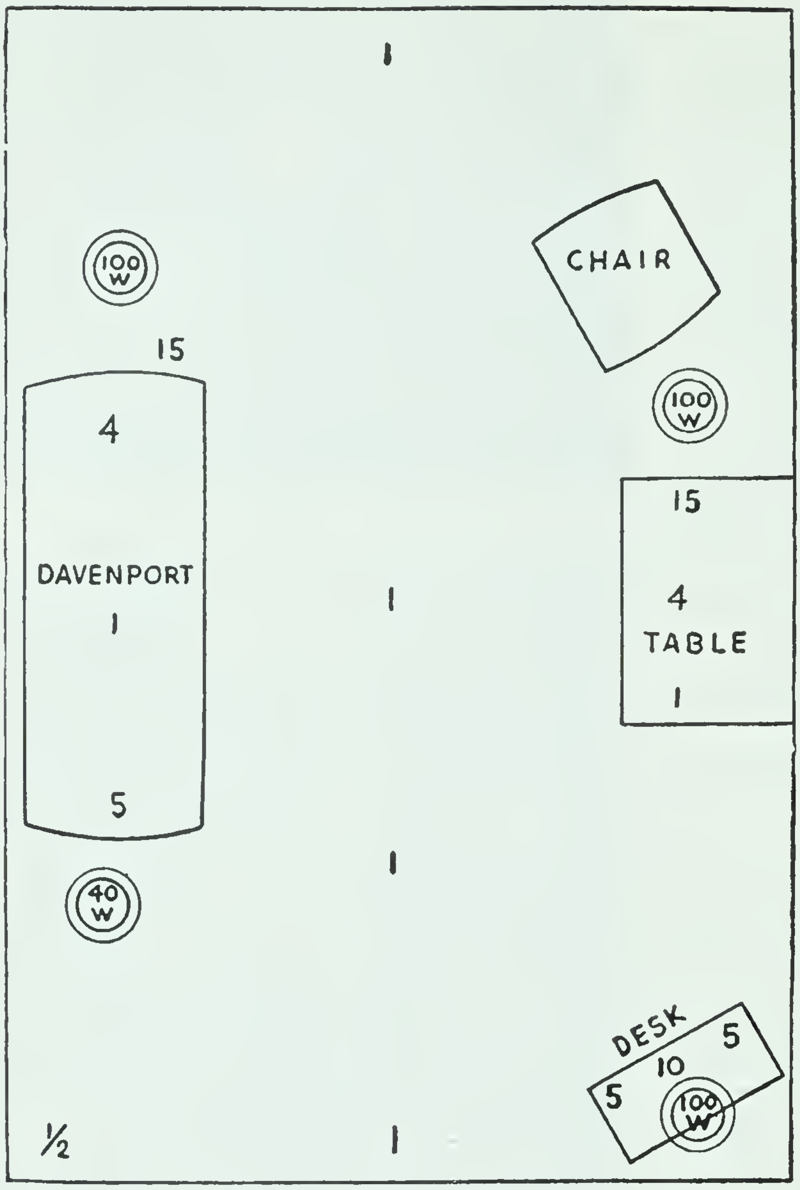
At present there is only one satisfactory type of floor lamp. It has a standard light socket into which the lamp screws base down. Around the lamp is a bowl of frosted or opal glass which diffuses the light. The lamp shade is white inside, and is made at such an angle that the light spreads over a fairly large area. A large part of the light shines on the ceiling to provide general illumination in the room, which makes the light more uniform.

The inexpensive student-size lamp requires a 100-watt standard bulb, and no other should be used in it. There is another lamp of this type with a three-way bulb; that is, the lamp contains two filaments using 100 and 200 watts. Either or both may be used at one time. This lamp with the three-way bulb is considered a poorer buy than the lamp using the standard bulb. Both the lamp and bulb are costly, and the brightest light from the 300-watt filament frequently causes glare in an ordinary room. Two student lamps placed at opposite ends of the room provide much better light than does one three-way lamp, because the light is spread more uniformly. Floor and table lamps are far from satisfactory lighting devices. Their chief advantage is that one can get near enough to the source of light to obtain sufficient brightness for close work. We shall now discuss types of lighting that are satisfactory.



Courtesy Westinghouse Electric and Mfg. Co.

Compare the dim, glaring, spotty light at the top with the bright, diffused, even light at the bottom. The lamp in the bottom picture is a semidirect lamp with a diffusing bowl.



This map of a living room shows the brightness of light in foot-candles in various parts of the room. The three semi-direct, 100-watt lamps and the 40-watt bridge lamp are indicated by circles. Note the dimness of the room illumination.

What is good general room illumination? There are two types of general illumination. *Direct* illumination comes either from bare bulbs or from bulbs in frosted diffusing bowls. Direct lighting lamps are sometimes placed in a recess in the ceiling. The light then shines through a pane of frosted glass downward into the room. Direct lighting is economical and, if properly used, is not injurious to the eyes. Much direct lighting is badly used.

In *indirect* lighting the light is reflected from the ceiling downward into the room. Light may be reflected downward into the room from lamps recessed behind a molding around the wall near the ceiling. Upside-down metal shades are also used to reflect light to the ceiling. Indirect lighting is a pleasing general illumination but is expensive and inefficient.

Many lighting fixtures on the market combine direct and indirect lighting.

What is good wall and ceiling color? Ceilings should be white because white reflects about 80 per cent of light. Walls should be light in color but not white because of the danger of glare. Most colors reflect less than half of the light falling upon them. Unusual interior decorating plans which use

red, blue, green, or any dark ceiling and upper wall color should not be used in living or work rooms.

Is good lighting important? Bad lighting produces eyestrain, nervousness, muscle tenseness, fatigue, headache, and indigestion. Accidents occur more often when people work by dim light, work is slowed up, and the number of errors increases when insufficient light is used.

Proper lighting increases efficiency in doing work and may improve the health of those suffering from eyestrain.

For general illumination 100-watt bulbs in proper lamps or fixtures are best. Desk lamps, the lamp over the stove and sink, and bathroom lamps should be provided with 60-watt bulbs. Stair halls should have 60-watt bulbs.

Demonstration. How Is Light Used?

What to use: Projector *or* box and candle, frosted glass, sight meter (may be borrowed from light company), cardboard one-foot square.

What to do: Throw on the wall a beam of light from the projector or from a candle inside a box in which a slit is cut. Put the piece of frosted glass in the beam of light, and note the change in its appearance.

Measure the illumination of the room with the lights on and off.

Measure the brightness of light one foot, two feet, and three feet from a single lamp in a darkened room. Hold the cardboard one foot from the candle so that the shadow falls on the blackboard. Measure the shadow and calculate the number of square feet in it.

What was observed: Record briefly your observations.

What was learned: How is light diffused? What factors affect brightness of light?

Exercise. *Complete the following sentences:* Candlelight is not —1— enough for adequate seeing. A glass-topped desk may cause eyestrain from —2—. Sunlight in a room produces a lack of —3—. A lamp producing 100 foot-candles at one foot distance gives a brightness of —4— foot-candles at five feet. Sunlight may be —5— times as bright as moonlight. The light meter is a device for measuring light by the amount of —6— it produces when shining upon a —7— cell. Light reflected from the ceiling is said to be —8—. A bare lamp gives the —9— type of lighting. The only satisfactory color for a ceiling is —10—.

Science activity. Make a small hole in a newspaper. Look through the hole toward a bright light, and try to read the print near the hole. This experiment shows you what is meant by glare.

4. How do we use reflectors of light?

When you go to amusement parks you may see yourself in the crazy mirrors as you never look (you hope) in real life. Yet in your mirror at home, you look quite normal. Have you ever wondered why the curved mirrors make you look as they do?

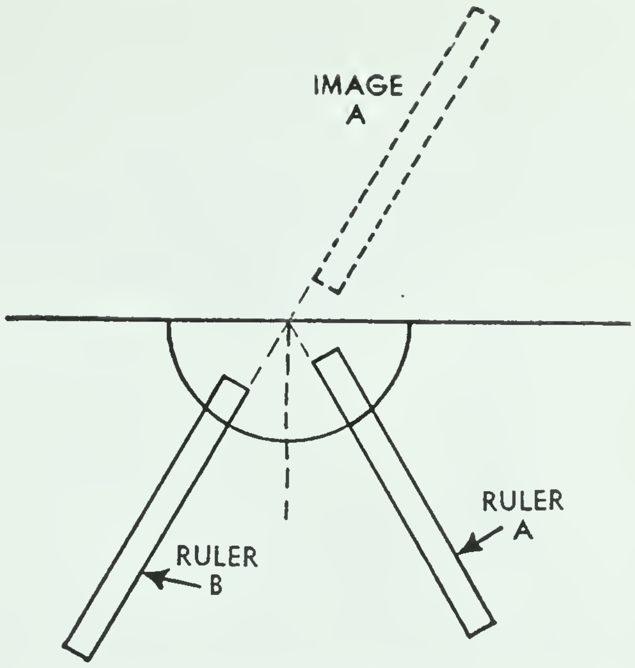
How is light reflected? Light is reflected by surfaces through which it does not pass. The best reflecting surfaces are mirrors made of highly polished metal and ordinary silver plated mirrors. Certain white chemicals, such as magnesia, snow, and zinc oxide, reflect as much light as do mirrors, but scatter it so that we do not see reflections on their surfaces. All these objects reflect more than 80 per cent of the light falling upon them. Among the poorest reflectors are soot, black velvet, and black-tar paving material, all of which reflect less than 5 per cent of the light falling upon them.

When light strikes a surface and is reflected, it leaves the reflecting surface at the same angle at which it strikes. To illustrate this, lay a ruler upon a table in front of a mirror, placing both upon a piece of paper. Stand the mirror up. Draw a line along the back edge of the mirror and along the edge of the ruler, and measure the angle at which the light strikes the mirror. Lay a second ruler upon the paper, lined up with the image of the first ruler in the mirror. When the second ruler and the image seem to be in a straight line, draw a line along the edge of the second ruler, and find its angle in relation to the mirror. The first angle, the angle of incidence (direction of approach), equals the angle of reflection. This observation is called the law of reflection.

When light strikes an uneven object, it is scattered because of the varying angles of the reflecting surfaces. Light is scattered or *diffused* by snow, dust in the air, and clouds. Diffusion of light causes dawn and twilight.

Where is the image in a mirror? You have noticed that

your image in a mirror is reversed, that is, your right hand becomes the left hand of the person you see in the mirror. Print is backwards. Moreover, you see the image, not at the surface from which the light is reflected, but at a distance behind the mirror apparently equal to the distance from the mirror to the object reflected. If you are four feet from the mirror, you are eight feet from your image.



You can test the law of mirrors with this apparatus.

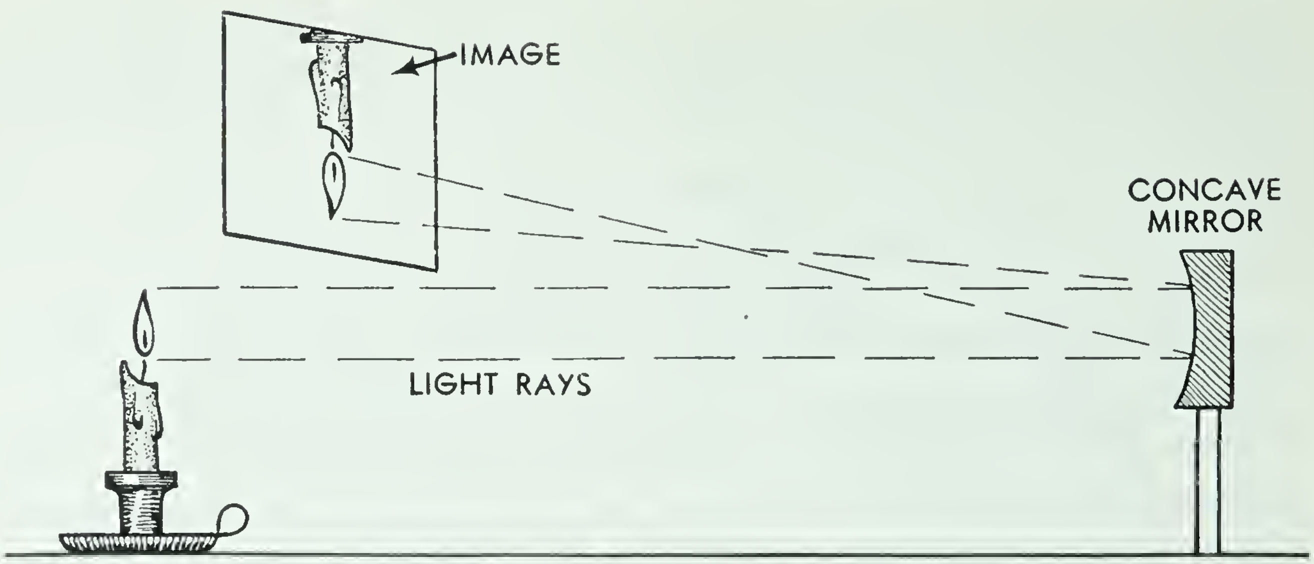
Actually, there is no image in a mirror at all, as a kitten learns when it runs around the mirror to find the second cat. An image that is not where it seems to be is called a *virtual* image.

Because the virtual image is apparently behind the mirror, the use of mirrors increases the apparent size of rooms and gives a feeling of spaciousness that many people desire. In decorative use of mirrors, we must avoid reflecting light into the eyes of persons who must sit facing the mirror. Mirrors are common sources of glare.

What is a concave mirror? One of the most important means of controlling light is the concave mirror. The word *concave* means hollow and rounded. (To help your memory—a cave is hollow!) The inside of the bowl of a spoon is concave. A concave mirror brings light rays together. The extent to which rays are brought together depends upon the curvature of the mirror.

The automobile headlight reflector is a concave mirror. The lamp filament is put at the center of the curvature—that is, if a circle were drawn with the lamp at the center, part of the circle would lie along the surface of the reflector. The rays that shine out in all directions from the lamp are concentrated by the headlight reflector upon the road as a single beam of nearly parallel rays.

The concave mirror is used for a reflector in most search-



A concave mirror projects an image upon a screen. To see the image clearly, the screen should be shaded. Note the position of the image.

lights. Motion picture projectors usually have a concave mirror behind the lamp, which almost doubles the amount of light available to illuminate the image upon the film.

The image produced by a concave mirror can be projected upon a surface. With a concave mirror, a lighted candle, and a card, you can project an image of the flame, as shown in the diagram. In order to make the image visible, the card must be shaded from the direct light of the candle. The image of the candle flame on the card is called a *real* image, for it has an exact location upon the surface of the card.

When light rays from a distant object are brought together at a point, they are *focused.* All the light rays from the tip of the candle flame which strike the mirror are brought back together, or focused, at a corresponding point on the card. All the rays from the bottom of the flame are focused at another point, producing an image of that part of the flame. The image of the flame is inverted and reversed by the concave mirror.

The concave mirror is used in the astronomical telescope to project an image to be photographed. A star can be photographed by using the concave mirror to focus the dim light of the star on a photographic film. The largest concave mirror is used in the 200-inch telescope.

The concave mirror is a magnifier, for the light it brings to the eye seems to come from an object larger than the actual object. Because of this, concave mirrors are useful in study-

Courtesy Harold Bither

Many ancient stories tell of people using quiet pools as mirrors. Here we see an entire lake so quiet that its surface serves as a perfect reflector.

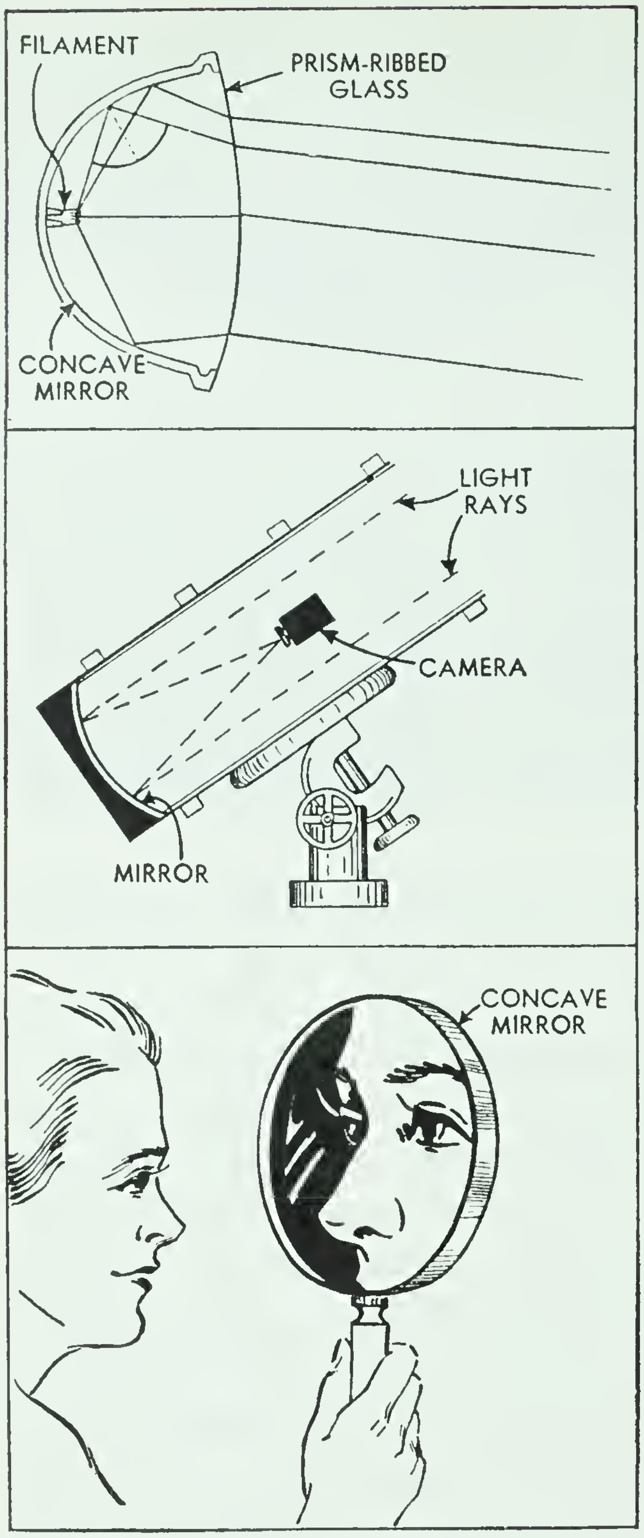
ing the skin for removing blemishes. Many shaving mirrors and dressing table mirrors are concave.

What are convex mirrors? The convex mirror is exactly opposite in shape to the concave mirror. It is rounded outward like the outside of the bowl of a spoon. The convex mirror spreads light rays and makes objects look smaller than they really are. Convex mirrors are useful in powder compacts, for they enable a woman to see her entire face at one time. The convex mirror is also used as a rear-vision mirror, making it possible for the driver of a car to see all the road behind him on a reduced scale in the mirror.

How are funny mirrors made? The mirrors in the amusement parks are unevenly matched sections of cylinders—some parts of the mirror being concave and some convex. When one stands at the right distance, the concave mirror enlarges the image, and the convex mirror reduces it, so that the parts of the body are changed in proportion.

Demonstration. How Do We Use Mirrors?

What to use: Plane mirror, concave mirror, paper, rulers, pencil, protractor, candle, cardboard.



Concave mirrors have three important uses: they serve as reflectors to concentrate beams of light; they are the essential parts of the largest telescopes; and they serve as magnifiers.

What to do: Measure the angles of incidence and reflection by the method described on page 246 of this problem.

Project and study an image of a candle flame, following the information given on page 248 of this problem.

What was observed: Make simple sketches to illustrate your observations in each part of the demonstration.

What was learned: How do these demonstrations illustrate the law of mirrors?

Exercise. *Complete the following sentences:* Light rays are —1— when bent by a surface through which they do not pass. The angle of —2— equals the angle of —3—. A person five feet from a mirror is —4— feet from his image. —5— mirrors focus light rays at a point. —6— mirrors are used in reflectors and telescopes. —7— mirrors reduce the apparent size of the image. —8— mirrors are used for rear-view mirrors. Light reflected from irregular surfaces is said to be —9—.

Science activity. 1) Obtain shaving and convex rear-view mirrors, and study your image in each.

2) If you can afford a few dollars for materials and can spend most of your spare time for several weeks upon the work, make a reflecting telescope. Many boys have made such telescopes and have learned much about astronomy from their use. You can obtain much information from the *Scientific American* magazine to help you build your telescope.

3) Obtain a mailing tube and two mirrors and construct a periscope.

5. How do the refractors bend light?

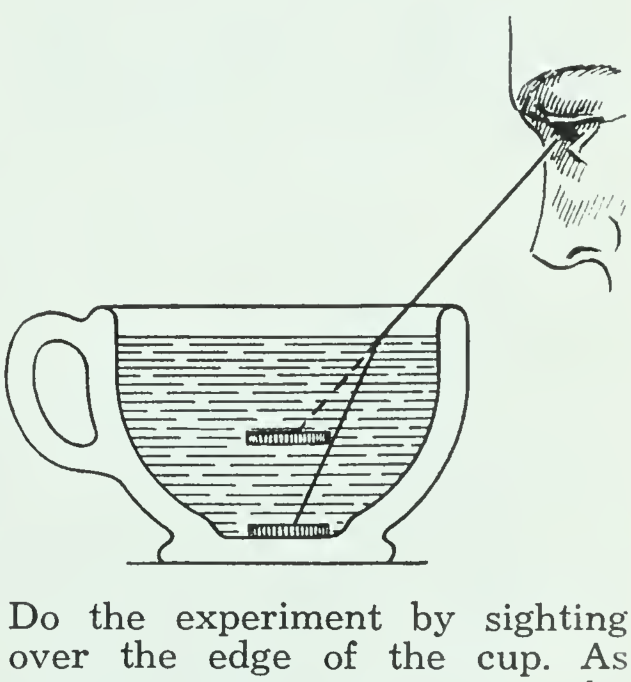
You have learned that reflected light is bent by surfaces through which the light does not pass. Light is also bent as it passes through objects of different densities. This second type of light bending is called *refraction.*

How does water refract light? If you put a pencil in a glass of water, the pencil seems to be broken at the surface of the water, and the part beneath the water seems to be curved and changed in size. As you turn the glass of water, the pencil seems to change shape.

Objects on a lake bottom seem to be nearer the surface than they actually are. Some Indians use spears to catch fish. The fisherman stands upon the bank with his spear poised so that he can throw it instantly at any fish he may see in the water. He aims, not at the point where the fish seems to be, but at a point considerably below the fish. It is necessary to make a correction for the refraction of light.

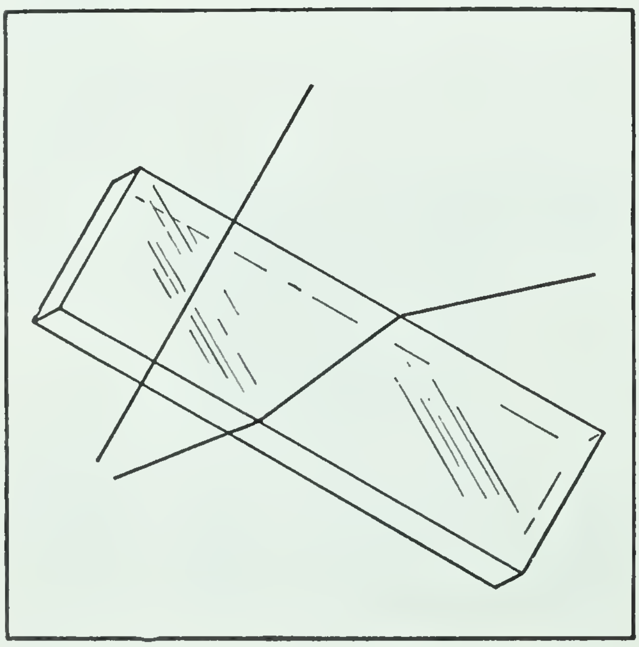
If you put a coin in the bottom of a cup so that you can barely see one edge of it and, without moving the eye, coin, or cup, pour water into the cup, the coin becomes visible. The refraction of light actually makes it possible to see around a corner.

Does air refract light? The air is not equally dense at all places. Warm air is less dense than cold air, and upper air is less dense than air near the surface of the earth. There are various conditions under which light is refracted by air. One of these is the mirage. You have heard or read stories of weary, thirsty desert travelers seeing beautiful lakes which seem always to stay in the distance. The imaginary



Do the experiment by sighting over the edge of the cup. As someone pours water into the cup, observe the coin.

Courtesy Bausch & Lomb Optical Co.
The law of refraction was discovered as the result of experiments performed with four pins and a piece of glass. The discoverer, Willebrord Snell, holds in his hand drawings showing the path of light through the glass. The drawing below shows how you can do the same experiment.



lakes are the result of refraction and reflection. There is a layer of hot air along the ground in which the sky is reflected. The reflected light is then bent, as it passes into the air, and again comes to the earth where it strikes the eye of the traveler. The blue color of the sky is mistaken for a lake.

Air is dense enough to refract light even at a height of about 100 or 200 miles. When sunlight approaches the earth at an angle less than a right angle, the light is bent earthward by the air. Light that would otherwise miss the earth entirely is thus refracted to make the day a bit longer in the morning and evening than it would otherwise be. We actually gain about 40 hours of daylight a year because of refraction at sunrise and sunset.

Because light strikes the polar regions at a slanting angle, the total amount of extra sunlight there is about 65 hours more each year than is received at the equator.

Does glass refract light? You can measure for yourself the refraction of light passing through a piece of glass. Obtain a piece of cardboard and a small square piece of plate glass. Place the

glass upon a paper on the cardboard. Thrust two pins into the cardboard. Then, beyond the piece of glass, thrust two more pins in line with the first two, as seen through the glass. Draw lines as shown in the diagram, and you will have a picture of the path of a beam of light through the glass.

The glass prism is used to separate white light into the colors of which it is composed. Because the eye is easily deceived by colors and cannot separate mixed colors, the prism is invaluable in finding the true color of light.

Courtesy Bausch & Lomb Optical Co.

Joseph Fraunhofer, the inventor of the spectroscope, was the first to measure the dark lines in the spectrum of sunlight.

Each element, when it is hot enough to give off light in its gaseous state, produces a combination of colors which is produced by no other element. By passing the light through a prism and by measuring exactly all the lines of colored light which are produced, we can learn what element is being studied from the light it gives off. No one element gives off all colors. There are gaps in all spectra. Colored bands of light from an element are separated by black or unlighted bands. By throwing the spectrum upon a screen and carefully measuring the location of the bands of darkness and of color, we can identify any element. The device which is used for this work is called a *spectroscope*. It contains one set of lenses for throwing a beam of light upon the prism, a screen built in with a scale measured upon it, and a magnifying glass or telescope for looking at the scale.

The eye is unable to distinguish blended colors. When you think you see a red light, it may really be a mixture of red, orange, and green. If a beam of red light is passed through a prism, the colors are separated and each can be seen. Matching colors is best done by use of the spectroscope.

Is refraction useful in controlling direction of light? The

concave mirror is used to concentrate the beams of a headlamp. To pull the beam of light down on the road, a lens is placed in front of the lamp. This lens is made up of a series of ridges or flattened prisms. These prisms do not bend the light enough to separate it into colors, but turn the whole beam toward the road.

Prism or ribbed glass is used in windows to throw light into the room. Ordinarily, light falls upon the floor a short distance from the window. By putting prism glass in the window, the light may be thrown across the room. Prism glass must be used carefully because of the danger of glare from the rays of light thrown into the room. One should never work directly facing a window in which prism glass is used.

What is the best refractor? The white diamond is a crystal of carbon. Colored diamonds contain traces of other minerals. A diamond is beautiful because it refracts light much as a prism does, separating the white light into colors. The diamond is cut to give the greatest possible amount of refraction and reflection of light. A diamond bends refracted light about twice as much as does water. The amount of refraction produced by glass is only two-thirds that produced by a diamond.

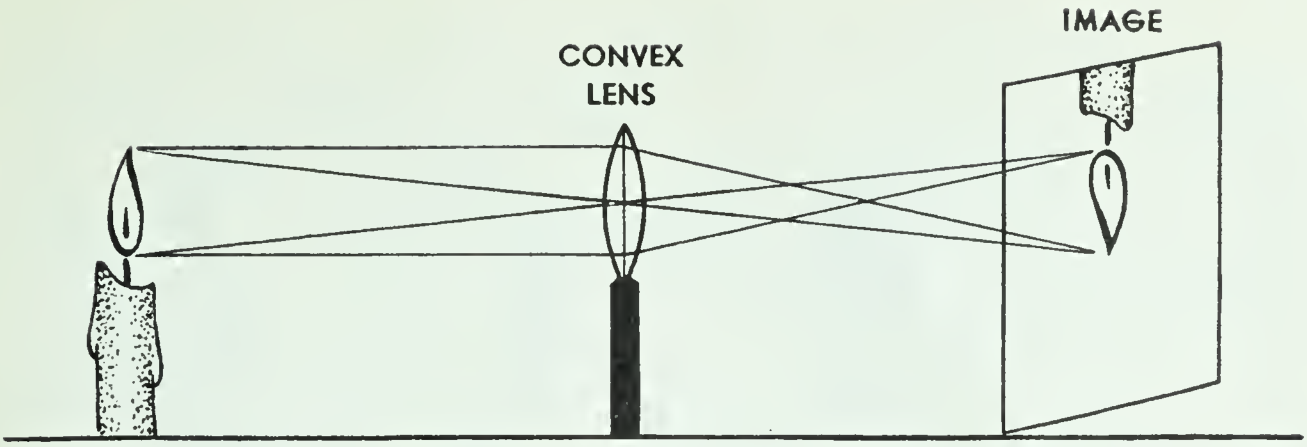
Demonstration. How Is Light Refracted?

What to use: Projector or sunlight; red, yellow, blue, and green cellophane; cardboard; glue; prism; water glass; pencil; ribbed glass.

What to do: Prepare four filters as follows: Cut a hole about two inches in diameter in a piece of cardboard, and over the hole attach cellophane with the glue. Shine sunlight or light from the projector upon the prism. Place the prism in such a position that a spectrum falls on a white wall or ceiling. In turn, place each of the four cellophane filters in front of the light beam, causing the colored light to fall on the prism. Observe the spectrum upon the wall carefully. Observe what colors actually pass through each filter.

Hold a piece of ribbed or prism glass in the projector beam.

Place a pencil in a glass of water, and observe the changes which you can produce in its appearance.



A convex lens may be used to project a real image upon a card. Note that the rays of light are brought together or focused at a point.

What was observed: Make a record of the colors which passed through each filter. Was the cellophane color actually pure or a combination of blended colors? What changes occurred in the appearance of the pencil?

What was learned: How is the prism used to study color? What is refraction?

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* refraction, spectrum, water, glass, density, mirage, element, prism, bending spectroscope, diamond.

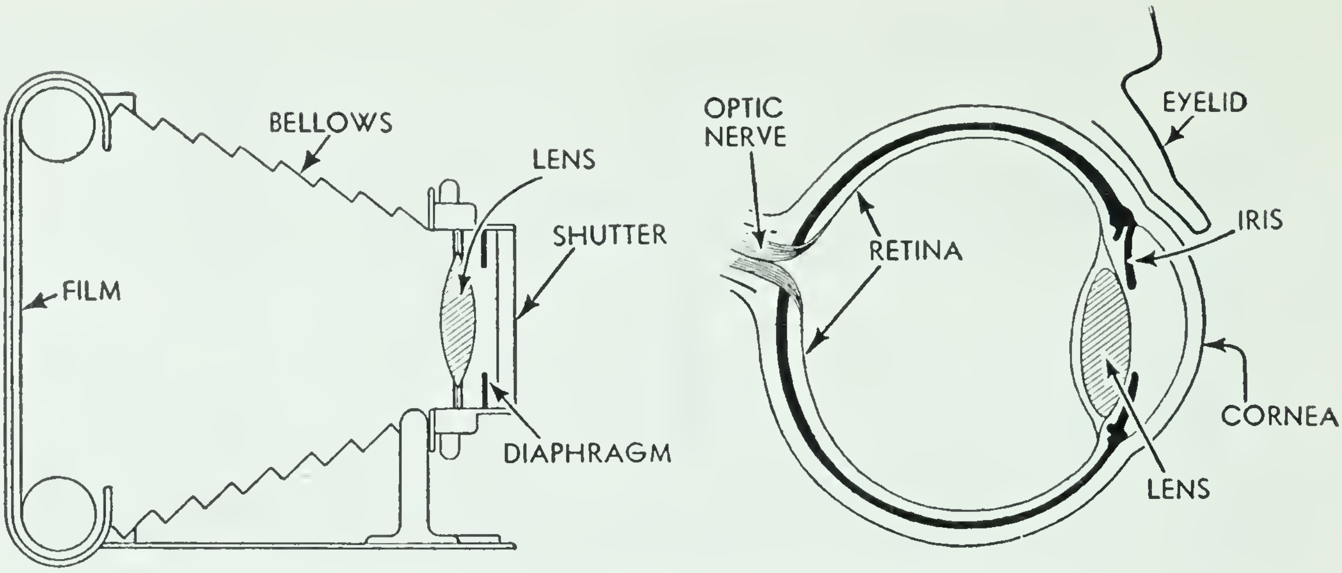
Science activity. Make a refraction exhibit, using pieces of glass, bottles of water, and lenses you can obtain from discarded articles. Explain what each part of your exhibit does.

6. What are the common uses of lenses?

The convex lens is the most important of all aids to seeing. It is an essential part of the eye, of small telescopes and field glasses, cameras, projectors, microscopes, and magnifiers. Lenses are chiefly used to magnify objects and to project images.

What is a lens? A lens is usually made of glass. A convex lens is thicker in the middle than at the rim. A concave lens is thicker at the rim than in the middle. Both refract light.

Because a convex lens causes rays of light to come together or focus at a point, it will project an image. If you set up a candle, a lens, and a card, the candle and card may be moved so that an image of the candle falls upon the card. All rays of light from the tip of the candle which strike the lens focus at a point on the card. All rays from the base of the flame



The camera and the eye are similar in principle. The shutter corresponds to the lid, the diaphragm to the iris, the lens to the lens of the eye, and the film to the retina. What is the use of each part labeled?

focus at another point, and so on. The effect is to form an inverted image, which is a real image because it exists upon the surface of the card.

A concave lens spreads out rays of light. It diminishes instead of magnifying objects seen through it.

How does the eye refract light? The eye is a complex organ. It consists essentially of a convex lens, an opening or pupil through which light is admitted, and the retina in the back of the eye in which nerves are located. Each part of the eye is controlled by complex sets of muscles. Behind the lens is a dark chamber filled with fluid.

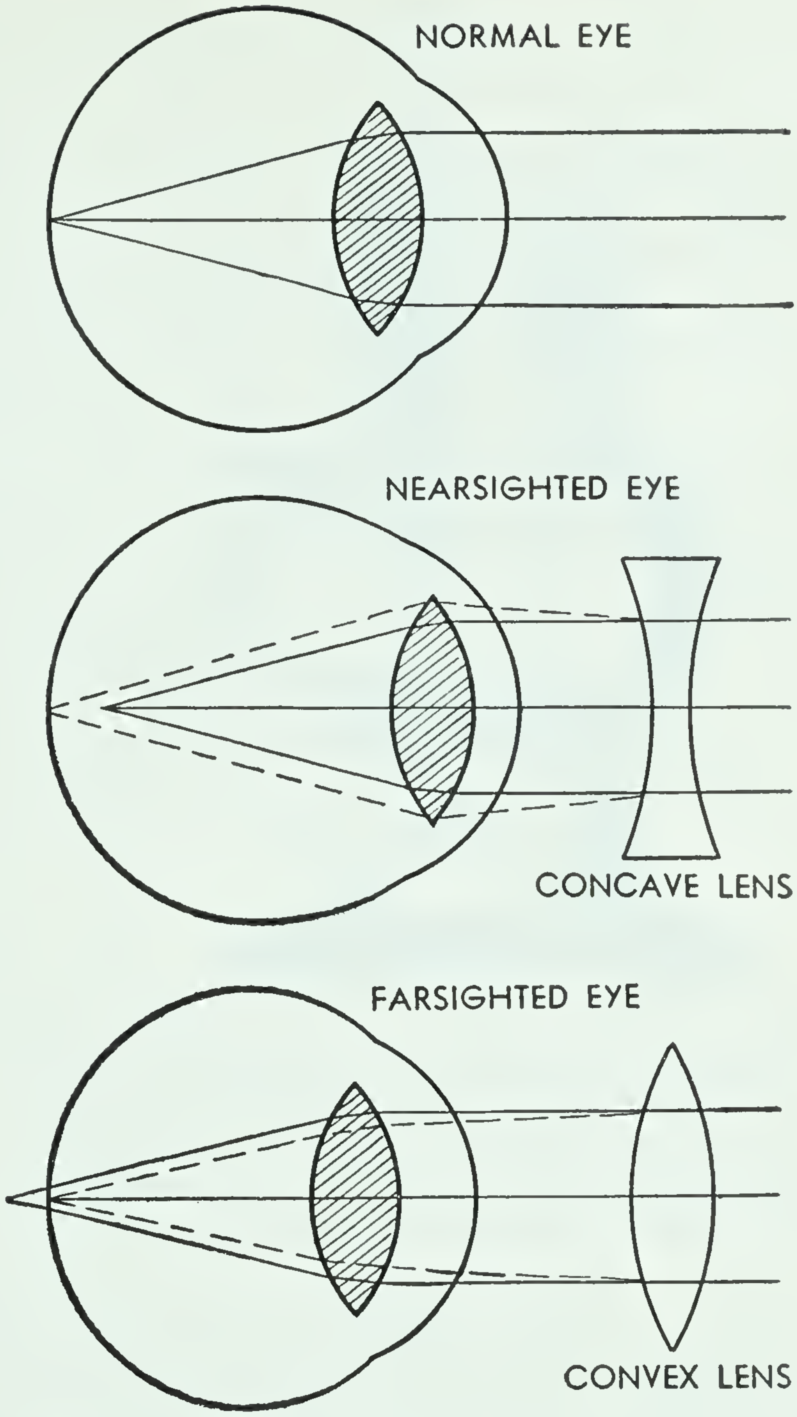
The light admitted to the eye is focused by the lens upon the retina. The lighter parts of the image set up strong nerve currents to the brain, but the darker parts set up less current or none at all. The pattern of the projected image is carried to the brain by the optic nerve. Where this nerve leaves the eye, there is a small blind spot. Some nerve endings are sensitive to light in proportion to brightness. Other nerves are sensitive to color.

The eye is often compared with the camera, for both have a convex lens which projects an image upon a surface sensitive to light, and a device for regulating the amount of light admitted.

How do eyeglasses correct eye defects? If the eye is too long, the rays of light focus in front of the retina. This condition, which is called nearsightedness, is corrected by use

of a concave lens which spreads the light rays slightly. If the eyeball is too short, the rays focus behind the retina. This condition, which is called farsightedness, is corrected by use of a convex lens which brings the rays of light together.

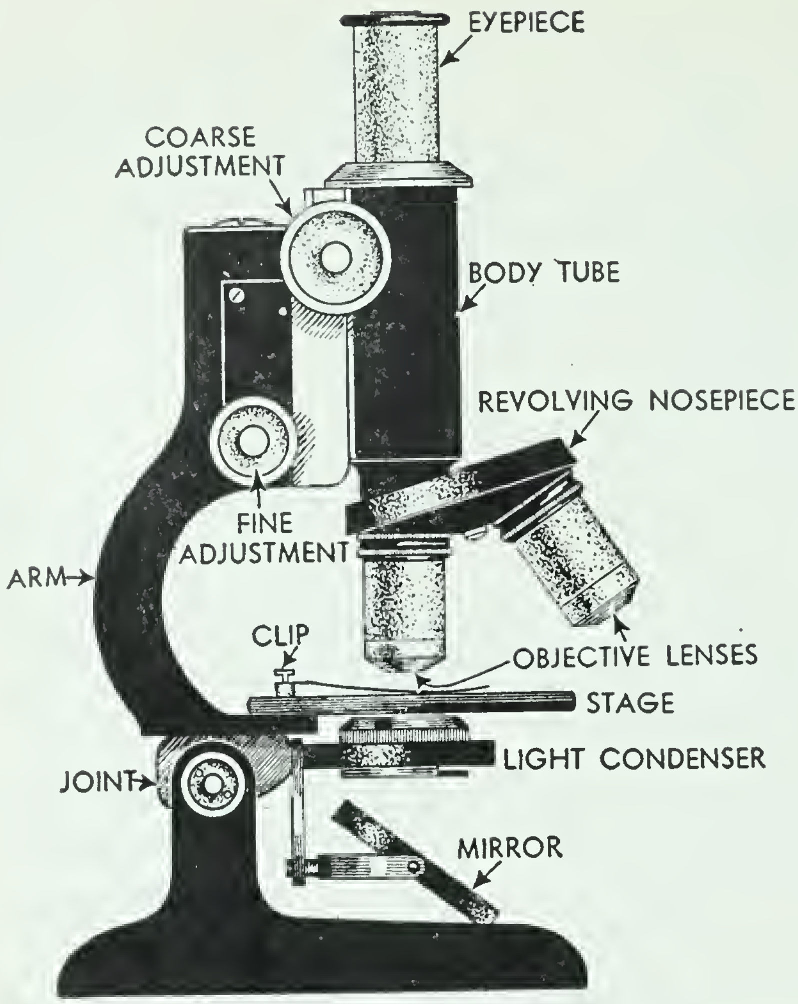
Astigmatism is a condition caused by irregularities in the shape of the lens of the eye. For example, vertical lines may be sharply focused, while horizontal lines may be blurred. Corrective lenses are so ground that the irregularity of the lens of the eye is offset by a corresponding irregularity, but in the opposite direction, in the eyeglass.



The lens of the normal eye focuses light sharply upon the retina. When the eye is not normal, use of glass lenses permits the error of the lens of the eye to be corrected.

Correction of eye defects is of utmost importance. The muscles of the eyes have enough work to do without having to overcome defects which can be corrected by use of glasses. One should have his eyes tested only by a person who is highly skilled in his work.

What is a magnifying glass? The common magnifying glass is a convex lens. It may be used for counting the number of weed seeds in samples of garden seeds, for looking at parts of flowers, for studying crystals in minerals, for counting



By comparing this drawing with your classroom microscope, you can learn the correct names of the various parts. Remove the eyepiece from the classroom microscope. Can it be used as a magnifier? What kind of lenses must it contain?

threads in cloth, for observing dissections of specimens in the science laboratory, and for reading. In each case, light rays are collected and bent in such a way that the object is made to seem larger than it actually is. Magnifying glasses may be used as burning glasses.

By using a convex lens as a burning glass we can find its focal length. Focal length is the distance from the center of the lens to the surface upon which an image or light spot is focused. To measure focal length, the source of light must be at a great enough distance from the lens that the rays are parallel. A burning glass projects an image of the sun upon a surface. If a burning glass works best at a distance of eight inches, its focal length is eight inches. A thin, slightly rounded lens has a long focal length; while a thick, rounded lens has a short focal length.

What is a microscope? The microscope has two sets of lenses: one set called the objectives, at the bottom of the tube, and another called the eyepiece, at the top of the tube. The microscope is a combination of magnifying glasses.

Microscopes usually have a number of combinations of lenses available, making possible different degrees of magnification. The microscope commonly used in general-science rooms magnifies from 40 to about 500 times.

What are telescopes and field glasses? Small telescopes

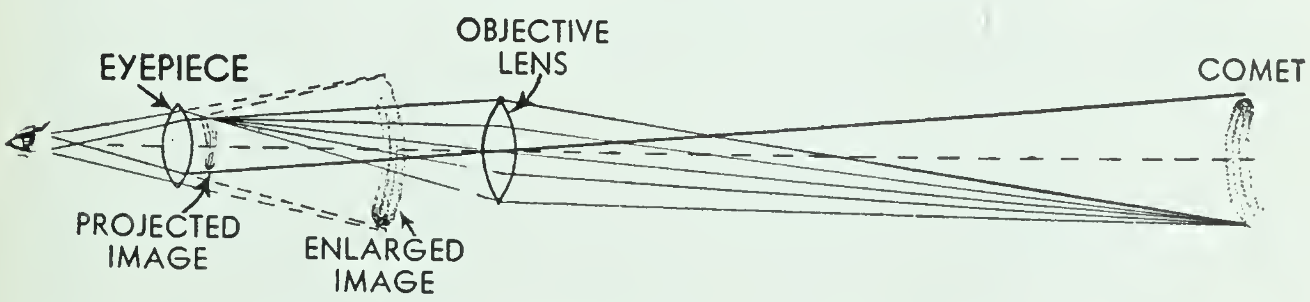
are always made up of combinations of lenses. A telescope has an objective lens, which has a long focal length, and an eyepiece lens of shorter focal length. Telescopes are long—the distance between the lenses equals the sum of their focal lengths. A field glass is a pair of low-power telescopes mounted together. In binocular field glasses the light is reflected back and forth in the tube by prisms, making possible the use of a shorter tube.

The telescope used in astronomy inverts the image. If you were to look through it at a house, the house would seem to be upside down. In field glasses and telescopes used for looking at objects on the ground, another convex lens is used to again invert the image, making it right side up.

The opera glass is made up of a convex lens used as an objective and a concave lens at the eyepiece. The concave lens is between the focal point of the convex lens and the lens itself.

How are lenses made? Most of the lenses in use today are made of glass. Only the most nearly perfect pieces of the best glass are selected for good lenses. The glass is ground by hand-controlled machines. Grinding is continued until in the best lenses of telescopes and cameras accuracies of 1/50,000 of an inch are obtained. Camera lenses consist of two to seven separate lenses placed in line. The cost of making good lenses is so high that most people cannot afford them. Cheap lenses are not ground but molded.

Lenses in the future may be made of a transparent plastic. The plastic refracts light as well as does glass and is cheaper to produce. The soft plastic is pressed by a hydraulic press into a steel mold and is as perfect as a glass lens ground by skilled workmen using expensive machines. After the mold



This diagram shows the principle of the lens telescope. The objective lens projects an image of the comet. The projected image is magnified by the eyepiece so that it appears to be greatly enlarged.

is once made perfect, lenses may be formed in it cheaply and accurately.

Poor lenses focus part of the light in one place and part in another, producing blurred images and streaks of colored light.

How can you choose a field glass? A good field glass is of great value in nature study and sport. It should be of not more than six power, and should have a high-quality objective lens of more than one inch in diameter. A large objective admits enough light to make it possible to see birds clearly when they are in the shade or to follow football plays on dark days. A prism binocular shows a wider field of view than does a field glass, but the field glass makes objects appear to be brighter.

Demonstration. How Are Lenses Used?

What to use: Convex lenses, lens holder, candle, cardboard, concave lens, simple optical bench.

What to do: In a darkened room project an image of the candle flame upon the cardboard, following the information given in the text. Substitute another lens, and project an image. Which lens has the longer focal length? Examine the lenses.

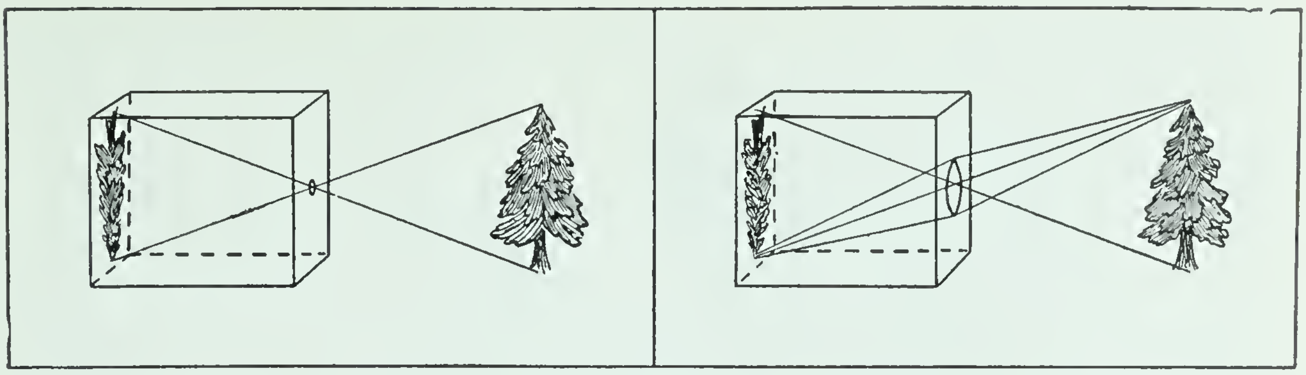
Hold the thinner convex lens in the left hand and the thicker in the right hand, or put them in holders on an optical bench. Look toward some distant object, and move the two lenses until the object may be clearly seen upside down.

Pass a concave and a convex lens around the class, letting each pupil observe which lens magnifies and which diminishes the objects viewed through them.

What was observed: Make simple sketches to explain what you observed.

What was learned: State four uses of lenses.

Exercise. *Complete the following sentences:* A concave mirror and convex lens are alike in that they —1— an image and —2— objects viewed with their aid. They are different in that the mirror —3— light and the lens —4— it. Images projected by lenses are —5— images. The —6— of a lens is the distance from the lens to the point at which the rays of light are focused. Images projected by lenses are —7— in position. The long eye is —8— and the defect is corrected by a —9— lens. The short eye is —10— and the defect is corrected by a —11— lens. Telescopes, field glasses, and microscopes are combinations of —12— lenses.



The advantage of a lens over a pinhole is that the lens admits more light and produces a much sharper image.

Science activities. 1) Hold a spectacle lens so that you can look through it toward a window, keeping only one eye open. Slowly rotate the lens. If the bars of the window seem to move, the lens is corrected for astigmatism. If the window looks smaller or larger, for what is the correction made?

2) Make a simple telescope of discarded lenses.

7. How is the camera operated?

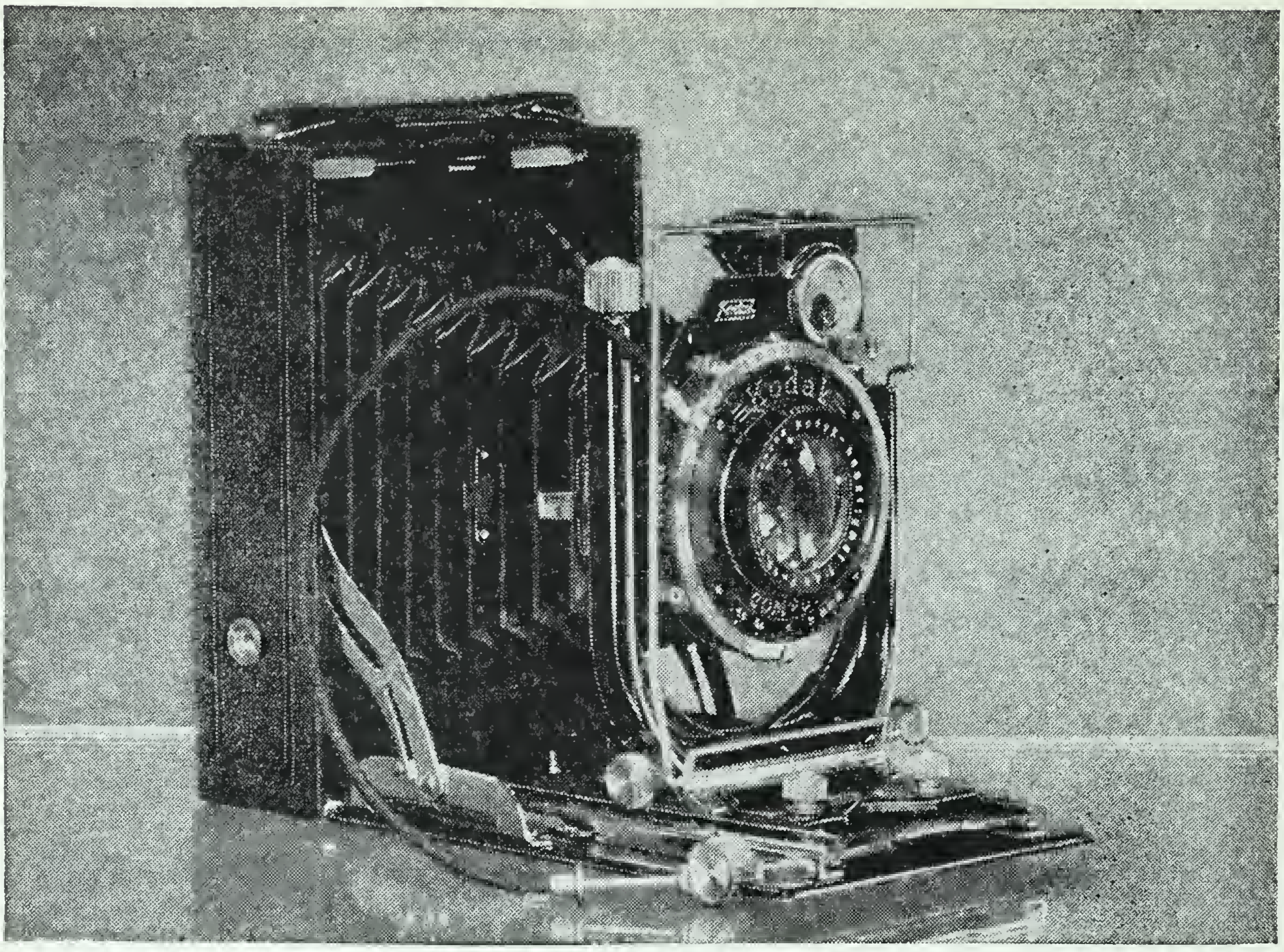
The camera today is an essential tool of science. It is used for photographing the stars and other objects in space. The camera is also used with the microscope. In connection with the spectroscope it is used to determine the chemical composition of matter.

The scientific use of the camera does not compare in amount with the everyday use of the camera for pleasure. Photography is the leading hobby activity in the United States. Almost everyone takes pictures for the pleasure obtained from having them.

What is a camera? The first camera was a dark room—the name coming from the Latin *camera* (a room) *obscura* (dark). Light was admitted through a hole in the wall or window shade, and an image was cast upon the opposite wall. Today we make pinhole cameras on this same principle.

Ordinary cameras have convex lenses. The lens projects the image upon the film in the back of the camera. Advantages of using a lens instead of a pinhole are that a sharper image is obtained, and a large enough opening may be used to take the picture in a fraction of a second.

The box camera is a lightproof box with a lens placed at the front end. There are two rollers and a key for holding

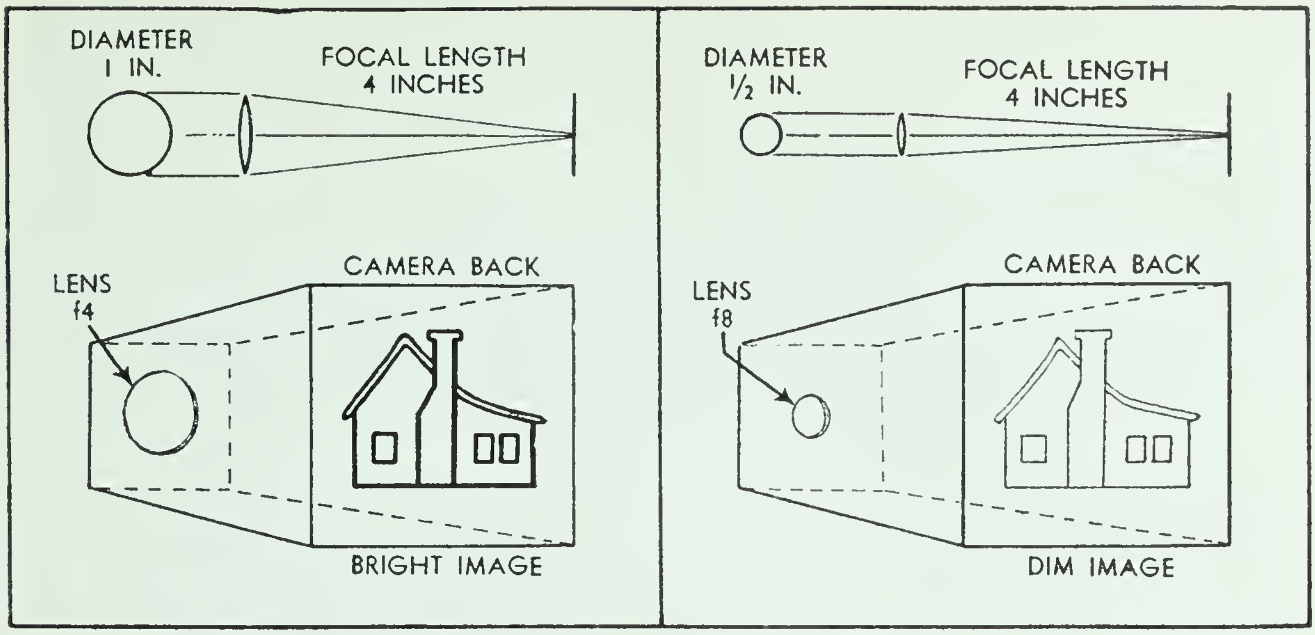


The shutter of this camera is adjusted by turning the bright metal ring. The spring is set by pushing the lever at the top of the shutter. The shutter is released by pushing the button at the end of the cable. The aperture is adjusted by moving the pointer below the lens. This camera is of the type used by many skillful amateurs.

and turning the film which is placed in the back of the box. The shutter is a disk of metal with a hole in it, fitting over a metal plate with a hole in it. When you take a picture, the movable disk of metal is snapped past the plate, permitting light to shine through both holes into the camera for about 1/25 of a second.

Other cameras are essentially the same as the box camera but have devices for focusing, for regulating the size of the opening which admits light, and for regulating the time of exposure.

How is a camera focused? The ordinary folding camera has a scale of feet, either upon a screw in which the lens is mounted or upon the bed (the lower support when the camera is opened) of the camera. When the screw is turned in toward the camera, the focus is set for distant objects. When the screw moves the lens away from the film, it is set for



The aperture (*f* value) of a lens equals the focal length divided by the diameter of the opening through which the light shines through the lens. Four times as much light enters the camera at *f*4 as at *f*8.

objects from 6 feet to 60 feet, depending upon the setting. You must guess the distance or measure it. If the focusing scale is upon the camera bed, the lens is moved back and forth by levers or other simple machines. Some expensive cameras are equipped with range finders to make focusing exact.

Some cameras are equipped with a ground glass back. When the camera is set up with the shutter open, the image is seen on the ground glass. When the picture is brought properly into focus and is pleasing to the eye, the shutter is closed and the ground glass is removed and replaced by the film held in a metal envelope or pack. The advantage of the ground glass is that you can see the picture before it is taken and can be sure it is in focus. Most professional photographers use this type of camera.

In another type of camera the image is reflected by a mirror and focused on a piece of ground glass at the top of the camera.

How do we set the camera for correct exposure? The aperture is the opening in the metal plate through which light is admitted. The amount of light admitted depends upon the size of the opening. The size of the aperture is indicated by the small letter *f*. The *f* value is obtained by dividing the focal length of the lens by its diameter. That is, if the lens

forms the image upon a film four inches behind it, and the lens is one inch in diameter, the *f* value is 4 ($4 \div 1 = 4$). If the diameter of this lens were one-half inch, the *f* value would be 8.

The *f* numbers on a camera are usually 32, 22, 16, 11, 8, 5.6, and 4.5. The smaller the number, the larger the lens. The box camera has an *f* rating of 16, and some ordinary folding cameras have a rating of 6.3. The larger the lens, the more expensive the camera. The aperture is set by moving a pointer.

The shutter is a set of metal leaves which open and close. The better shutters are operated by clockwork made as carefully as that of a fine watch. Cheaper shutters are operated by a simple spring. Ordinary folding cameras have three time settings: 1/25, 1/50, and 1/100 of a second. More expensive shutters have time settings ranging from one second to 1/200 or 1/500 of a second.

To obtain correct exposure, one must adjust both aperture and exposure time, after setting the lens for distance. The correct exposure depends absolutely upon the amount of light reflected by the object. The following table is helpful:

Brightness of Light in Foot-Candles, and Where Found

f OPENING	200 (NEAR WINDOW)	1000 (SHADE)	5000 (SUNLIGHT)	10,000 (BRILLIANT SUN)
5.6	1/10 sec.	1/50	1/200	1/400
8	1/5	1/25	1/100	1/200
11	1/2	1/10	1/50	1/100
16	1	1/5	1/25	1/50
22	....	1/2	1/10	1/25

This table is designed for use with Verichrome or Plenachrome film, for average subjects, such as snapshots of people and scenes. If a faster film is used, or if the objects are light, as snow or beach scenes, less time is required. If the objects are dark, the time should be increased.

To use the table, let us suppose we are going to take a snapshot in the sunlight on an average day. We may then set our camera at *f* 11. As we read down the column for *sunlight*

to the row 11, we find the number 1/50. We then set the camera at 1/50 of a second.

Suppose you wish to take a picture of your mother indoors on a sunny day. You place her within three feet of a window but not in direct sunlight, pull back the curtains, and run the shade to the top of the window. You place a large white card so that it reflects light from the window upon the shaded side of her face. The brightness is about 200 foot-candles, so you read down the first column. You may set your camera at 5.6 and use an exposure of 1/10 of a second if that setting is possible. Otherwise you must set it at *f* 16, and use the bulb to give one second.

The bulb setting permits the camera aperture to remain open as long as you hold your finger on the lever. For all exposures slower than 1/25 of a second, you must support the camera upon a tripod or some other solid support.

What equipment should we choose? There are in general two types of film for sale. The orthochromatic [ôr′thō̇·krō̇·măt′ĭk] film names end in *chrome*. Since these films are not sensitive to orange and red light, orange and red objects photograph black. Orthochromatic films are designed for outdoor photography and ordinary snapshots. The *panchromatic* films are sensitive to all colors and are used indoors and to photograph all objects containing red or orange coloring.

Filters are pieces of colored glass which are slipped over the lens. They may be used with panchromatic films. To make the sky dark and clouds white a yellow filter is used. A red filter makes the sky almost black. Exposure must be increased when a filter is used.

For a dollar you can buy a baby box camera that will take satisfactory pictures. For three or four dollars you can buy a much better box camera, with a built-in yellow filter and a lens that will take pictures near or far, on larger film. There is no use to buy a folding camera unless it has a lens opening of at least *f* 6.3. Such cameras cost from $12.50 upward. Good roll film cameras, with *f* 4.5 lenses and shutters with speeds from 1 second to 1/200 of a second, are the best buys in the $25 to $50 class. For prices above $50, many excellent cameras are available.

This picture was taken at f 5.6 at 1/300 of a second. What does this information mean? Note that the action of the galloping horses is stopped.

The candid camera, which uses a 35-millimeter film, is a poor buy. Most low-priced cameras of this type are poorly made and have cheap lenses. Good small cameras cost more than $50. All small cameras take pictures too small to see without having them enlarged, and this is expensive. The resulting enlargements are rarely entirely satisfactory. Most beginners will get much better pictures with a box camera than with a candid camera.

The best film size for most people is 2¼ by 3¼ inches with eight exposures in a roll. Pictures of this size are suitable for album use without enlarging, and the film is available at all drugstores.

Exercise. *Complete the following sentences:* A —1— is a light-proof box, into which light is admitted through a —2—. An image is projected by the —3— on a sensitive —4—. The position of the image is —5—. The inside of the box is black to prevent —6— of light. The —7— of the lens is the distance from the lens to the film when properly focused on a distant object. The aperture, or f opening, is obtained by dividing the —8— by the —9— of the lens. The amount of light that enters the camera is controlled by the —10— and —11—. For taking a picture on Verichrome film in the shade at f 8, one should use —12— second exposure.

Science activity. Organize a camera club. Projects you may

work upon are construction and use of pinhole cameras, developing and printing of pictures, use of the ordinary camera, contests of snapshots, and making records of apparatus setups in the classroom. You should learn to take pictures indoors. Bring cameras to class and learn to use them.

This snapshot includes several common errors. The picture is bad because of the shadow of the photographer, the tail of the second cat, the unsightly background, the crude box, and the location of the cat above the center of the picture.

8. How are good pictures made?

There is more to making a good picture than being able to operate a camera. Operation of the camera must first be learned, but making a picture is the goal.

How can you take a picture? The camera records everything in the scene impartially—the electric light wires, the billboards, the hydrants, the hole in the sidewalk. Until one studies snapshots, he does not realize how unsightly most familiar scenes really are.

The best light for taking pictures comes from the side and slightly behind the camera. Light from directly behind the camera rarely gives pleasing pictures. Light from in front of the camera often gives pleasing pictures, but great care must be taken to prevent light from shining on the lens. A shade must be used when the camera points toward the light.

Try to avoid getting too much into your picture. A good picture has one and only one center of interest. Plain backgrounds are advisable. For example, if you want to take a picture of your cat, place a white or gray cardboard or a sheet behind it.

How can you develop the film? If you should examine an exposed film by a very dim light, you would see no picture on it. Although the sensitive silver salts upon the film have been changed by the light, the picture is incomplete.

A solution of chemicals called the *developer* is used to bring out the image on the film. The steps in developing film are simple.

Mix the developer as directed on the package or tube. Put it in a glass, enamel, or hard-rubber tray. Mix an acid-fixing solution, also called acid hypo, according to directions, and pour it into a second tray. Fill a third tray with water. Solutions should be kept below 70 degrees Fahrenheit.

Put the trays where you can find them in the dark. The bathtub is a good place. Make the room absolutely dark, and wait one minute to check for stray light. Cover all cracks around doors and windows.

In the dark, take the film from the spool. Break the seal, and unroll the paper until you can feel the film with your fingers. Separate the film and paper, and when you come to the end of the film, tear it from the paper and throw the paper away. The film is stiff and springy. Hold it carefully to keep it straight.

First, wet the film thoroughly for half a minute in clear water.

Second, holding the film by the ends, as shown on the next page, dip it into the developer. Moving the hands up and down, run the film through the developer. Continue this, in the dark, for the length of time stated on the package, which will be between 3 and 20 minutes. Have some person in an adjoining room keep time, or count the seconds. You can do this with practice.

Third, at the end of the developing time, rinse the film in water for half a minute.

Fourth, run the film up and down through the fixing solution several times. Keep it covered with the hypo for 15 minutes, moving it occasionally. You may look at the film by dim light after it has been in hypo four or five minutes.

Fifth, after 15 minutes of fixing, transfer the film to water, and wash it in cold running water for one hour to remove the

fixing solution. Ten changes of water are necessary for complete washing.

Sixth, dry the film by hanging it where no dust will fall on it. The film may be held in a strong spring clothespin and hung on a cord run through the spring. Surplus water may be wiped off with a piece of *damp* cotton. The film dries in four to eight hours.

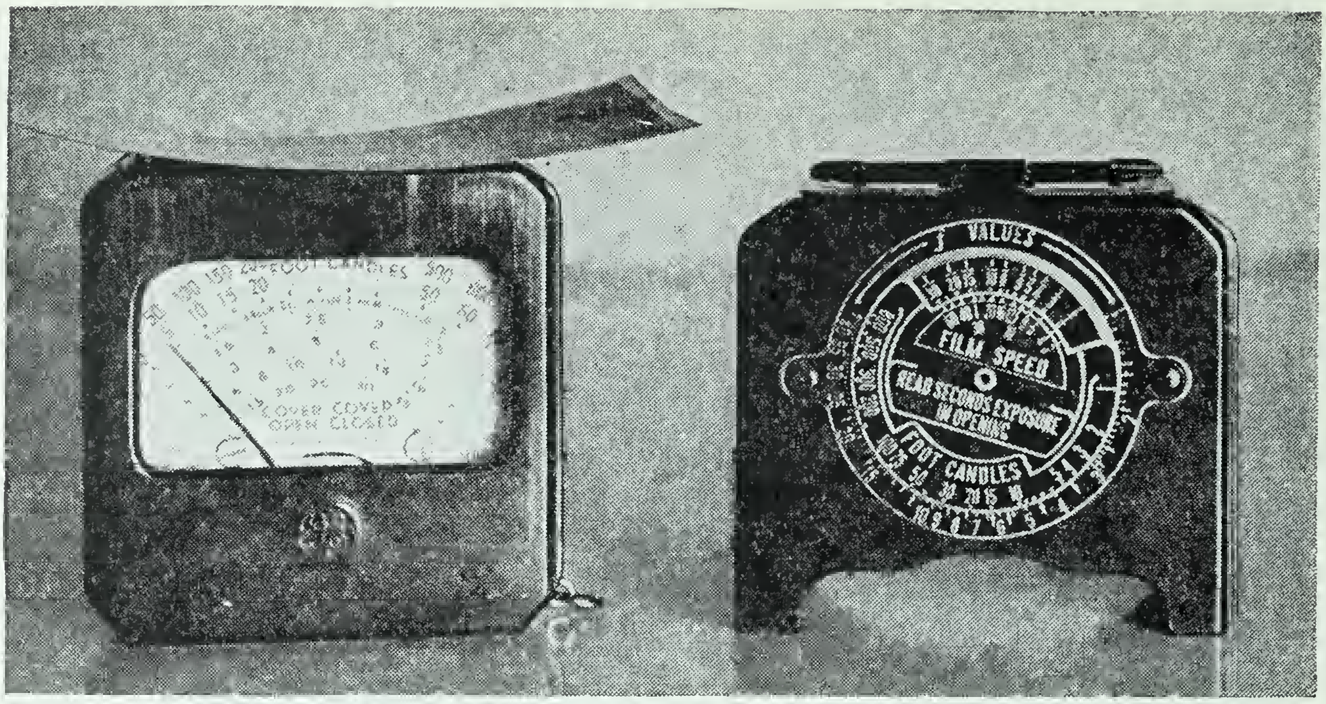
This is the correct method of holding film for tray developing. The hands are moved up and down to move the film carefully through the developer.

What happens during development? While you were moving film through the developer in the dark, the image was being formed. The silver salts which were exposed to the light were slowly changed to tiny grains of pure silver on the film. The silver grains are black and form the image. Just as the pictures in this book are made up of dots, the picture on the film is made up of grains of silver. The light portions of the original scene are darkest, and the dark portions lightest on the film, which is called a negative.

The fixing solution stops the development of the image and dissolves from the film the undeveloped silver salts upon it.

The silver salts are held in an emulsion of gelatine which is coated upon the film base. Because gelatine dissolves in warm water, it is particularly important to keep the film cool. The warmth of your fingers may melt the emulsion from the film.

Can you check correct exposure? You can check your exposure if you can obtain use of an exposure meter or sight meter. Note the reading of the meter as it is near a light. Then put your film over the sensitive cell, and read the amount of light shining through the film. A properly exposed and developed film lets through about 10 to 15 per cent of the light falling on it.



The film is placed upon the light meter (*left*) to measure its density. If a film lets about 10 or 15 per cent of the light pass through, it is easy to print. The cover of the exposure meter (*right*) is equipped with tables for calculating correct exposures for taking pictures.

How can you make a print? To make a print, you need printing paper, a printing frame, and solutions of developer and hypo. Fresh developer should be mixed. Some developers are used for both film and paper; others for only one. Hypo can be used several times if kept clean. No metal or rust should come in contact with any photographic chemical.

Printing is done by red light, such as is given off by a ten-cent 7½-watt red bulb. In a room that is dark except for the red light put the film in the printing frame, with the shiny side against the glass. On top of the film put the printing paper, with the shiny side toward the film. Put the back of the printing frame in place. If you want white borders on your print, cut out a black paper frame to cover the edges of the paper.

Hold the printing frame at right angles to, and one foot from, a 40-watt lamp, and turn on the light. After 10 seconds, turn it off. Take the paper from the frame and put it in the developing solution, leaving it exactly 45 seconds. Put the print in rinse water for five seconds; then move it to the fixing solution. It must remain in the fixing solution for 15 minutes.

In the negative (*left*), the dark objects appear to be light and light objects appear to be dark. In the positive, the brightness appears as seen by the eye.

If your print is too light or too dark, make others—exposing for longer or shorter amounts of time—until you get one that is exactly right in tone.

The print is washed for an hour in running water or in 10 changes of water. If you have a glossy paper, dry it on a polished ferrotype plate. Place the print face down on the metal plate, and roll it dry with a rubber roller. The print dries, curls up, and comes off. If the finish is not to be glossy, dry the print on a cloth or a blotter.

What developing set should you buy? Ready-prepared developing sets are available on the market for prices ranging from two to five dollars. However, old dishes may be used instead of trays. The film and paper can be placed between two pieces of glass held by spring clothespins instead of in a printing frame. The prints can be dried on cloth or on clean, polished glass. All you absolutely must buy are your chemicals, paper, and a red lamp. For your first prints, buy Number 2 print paper.

DEMONSTRATION. HOW ARE PRINTS MADE?

What to use: Acid hypo, Eastman universal developer, trays, negative, red light, printing frame, print paper, white light.

What to do: In the darkest room available—one without any light—set up the apparatus for printing pictures, and proceed as directed in the text.

What was observed: Write a brief description of the process of printing.

What was learned: What kind of changes produce pictures?

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* fixing solution, developer, water, negative, paper, light, red light, 15 minutes, 45 seconds, one hour, positive, drying.

Science activity. Arrange a darkroom at home following suggestions in the reference books.

9. How are motion pictures made?

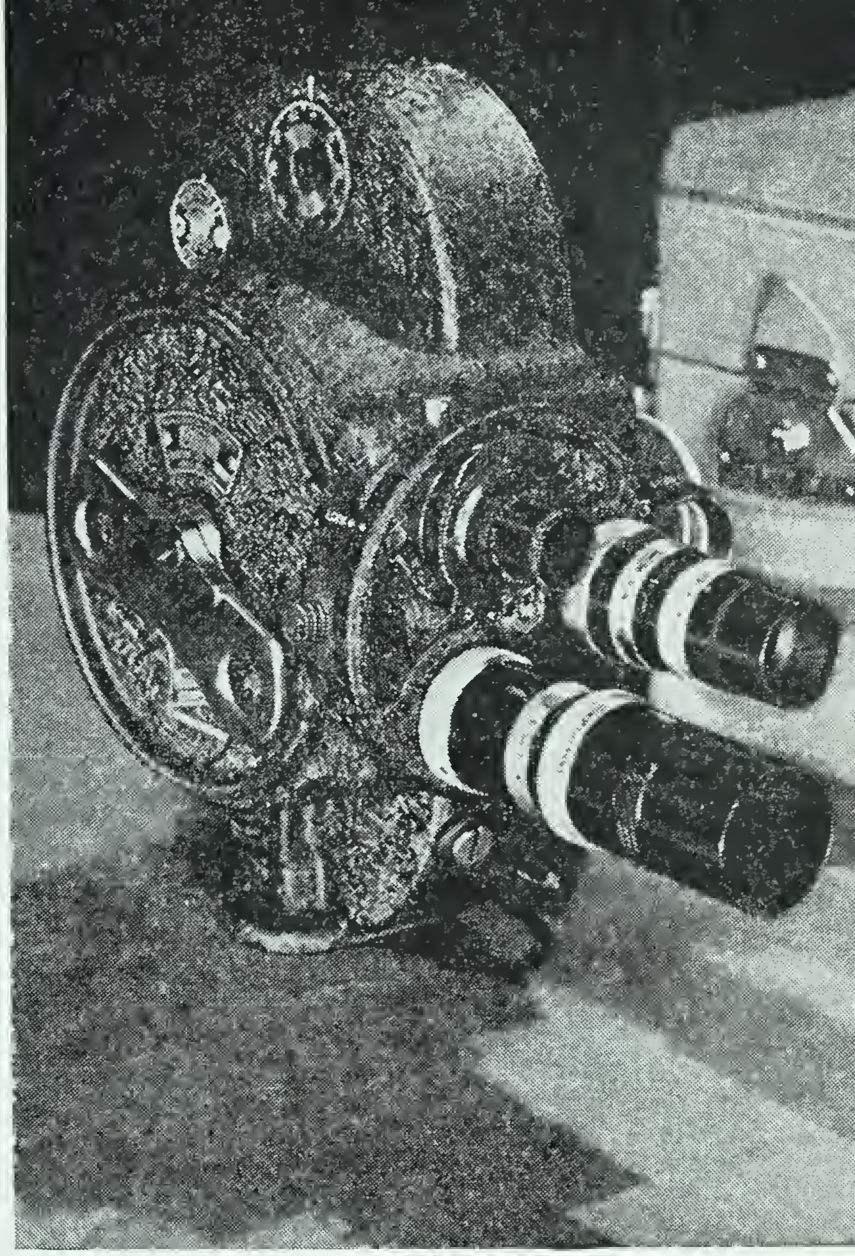
Today making and showing motion pictures is a major industry. It employs thousands of people in studios and more thousands in theaters. In one recent year more than half-a-million miles of motion picture film was manufactured in the United States. More than half the silver mined in this country was used in manufacturing film.

The motion picture ranks along with the telescope, the microscope, and the spectroscope as an important scientific tool. The motion picture camera reduces or increases speed, giving us a chance to see those things we otherwise would never observe. The opening of a flower is so slow that no person can see its growth, yet, by taking a picture every half-hour over a number of days, the action can be shown in a few seconds on the screen. The development of a chick in an egg has been speeded up for observation.

The speed of objects moving too fast to be observed is slowed down. Motion of the piston in an automobile cylinder or of a bullet leaving a gun cannot be observed directly by human eyes.

The camera combined with the microscope gives opportunity to study many objects difficult to see with the eye. Unusual objects in nature may be studied and recorded best

by motion pictures. Difficult technical processes are photographed and studied to learn methods of improving them.



Courtesy Bell & Howell Company

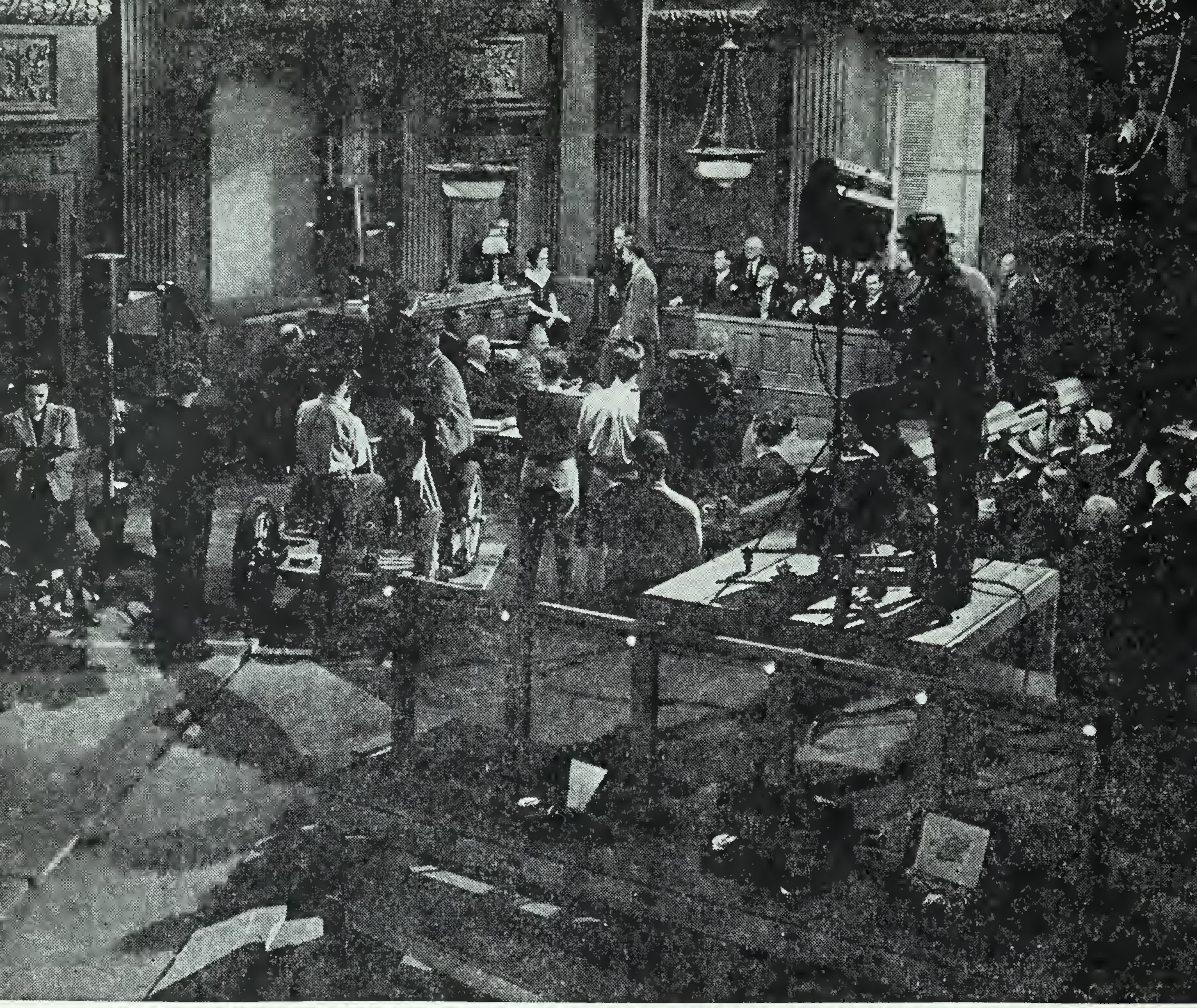
The three interchangeable lenses make possible taking pictures close up, at medium distances, or at long distances. The lens with the longest focal length is called a telephoto lens.

How does the motion picture camera work? The motion picture camera does not take motion pictures. Instead it takes a series of still pictures at a high rate of speed. The camera part of a motion picture machine is about the same as a good still camera.

The exposure time of a motion picture camera operating at normal speed is about 1/35 of a second. A rotating shutter makes the exposure automatically when the camera is operating. The film is moved between exposures, thus placing the next frame in position to be exposed. Sixteen complete exposures are made each second at normal speed. For slow motion 32 or 64 exposures are made per second. No matter how many exposures are taken in a second, they are shown at the rate of 16 to 20 frames per second.

The motion picture camera is equipped with a motor and a film holder. The motor is usually spring operated, and it moves the film and operates the shutter. The film is wound through the camera from one spool to another. It may or may not be enclosed in a magazine (a closed box). A magazine may be put in or taken out of the camera at any time without spoiling the film. Many cameras have a crank which is used to operate the mechanism.

The film has a series of holes along the edges into which sprocket teeth fit. There are 16 frames per foot and 4 holes



From "Hollywood Cavalcade," a Twentieth-Century-Fox Production

This scene shows how many lights are needed to make a movie. The table in front of the picture is used by the actors for applying make-up.

per frame in the large-sized film. The sprockets which move the film catch in the holes.

Cameras are made in three standard sizes. The commercial studio camera uses a 35-millimeter film. The standard amateur and educational size camera uses 16-millimeter film. Because of its smaller size, the 16-millimeter camera is less expensive to operate and easier to handle. But the pictures, being one-fourth the area of the 35-millimeter picture, are not satisfactory for theater projection. An 8-millimeter camera is popular only when low cost is the most important factor. It takes pictures which are fairly satisfactory to most people for use in the home, and it is small enough to slip into the pocket.

Inexpensive cameras have one lens which is used for all purposes. More expensive cameras have three lenses mounted

on a circular pivot in such a way that they can be changed by turning them into place. One lens is used to take pictures at close range, one for normal distances, and one for distant objects. This third lens is called a telephoto lens.

How is motion picture film developed? The cost of developing movie film is included in the cost of the film. The process of development is somewhat different from that used on ordinary film. The picture is brought out as a negative, then reversed so that it becomes a positive. The film you send in to be developed is returned as a positive.

Why do pictures seem to move? The eye is easily deceived. Sixteen times a second a nerve impulse travels from the retina along the optic nerve to the brain. Even though an object may not remain before the eye, the image stays on the retina for about 1/24 of a second. While the image from one picture is still on the retina, the screen is darkened, and another picture is moved into place in the projector. Another picture seems to fit into the motion instantly, although actually the screen is dark almost half the time.

The darkness lasts about 1/32 of a second, and the picture is shown for an equal length of time. If the film is run too slowly the pictures flicker, and we become aware of the intervals of darkness.

Is color photography practical? Color photography is today the most interesting of all fields of motion picture making. The color film is too complex in structure to describe here. It has three or more coats of chemicals sensitive to various colors of light. Such film is developed only by the manufacturers. Although it is entirely probable that great improvement is still to be made in color photography, the films now available take satisfactory pictures.

How may we produce motion pictures? Many people are now producing their own motion pictures. Cheap movie cameras, while not especially good, are in common use. Cameras may be rented in many cities. If you wish to make a satisfactory movie, you must use the right methods.

First, you must be able to take a picture and to know what will make a good picture when you see one. The same rules of planning and choice of background apply to motion pictures that apply to still pictures.

Second, you should have a story. If you want to take a picture of a person, don't have him stand grinning into the camera. Have him do something that he ordinarily would do. If your picture is to be rather long, write a scenario—an outline of the story—and practice acting it before you take the picture. Mix close-ups into the action freely.

Third, you must operate the camera correctly. Have enough light, and set the aperture correctly. Most indoor pictures taken by beginners are underexposed. Be certain that you know how the camera works before getting people in place.

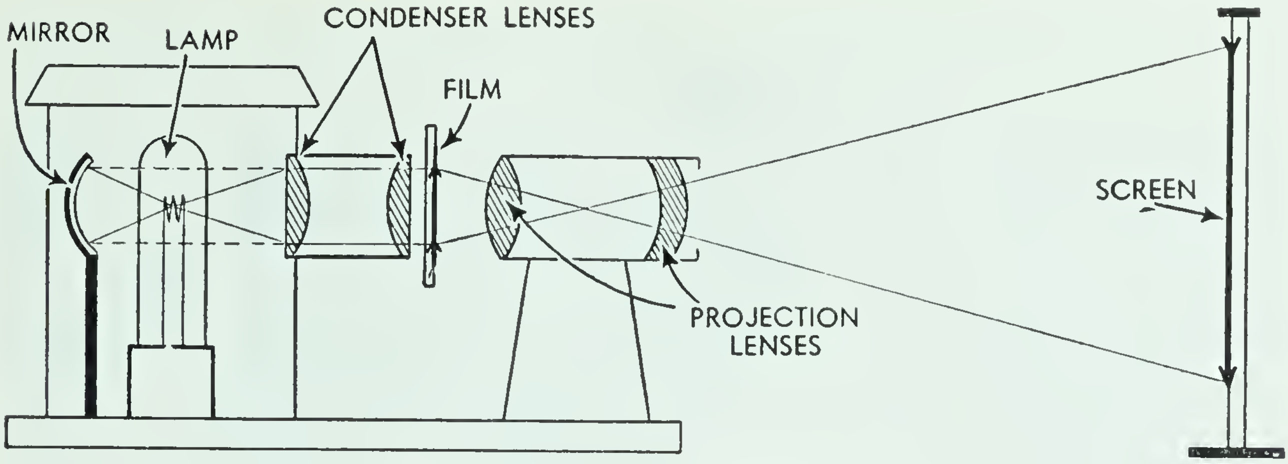
Fourth, hold the camera still. If possible, use a tripod. Never take movies from a moving automobile. Don't swing the camera around to get in all the scenery in one shot. Pictures taken while moving the camera are blurred. The picture should be taken for 10 seconds with the camera in one position. Then it should be stopped and moved to a new part of the scene. The only time the camera should be moved is to follow moving objects.

How long do films last? Motion picture films do not last indefinitely. At the end of five years they may be cracked and dry. They rarely last more than 10 years unless given exceptional care. Films should be reprinted when necessary. The film requires a reasonable amount of humidity to be kept in best condition.

The still camera has an advantage over the motion picture camera when a permanent record is desired. Pictures taken of the War Between the States are still in good condition, but the original motion pictures of the World War of 1914-1918 are not in usable condition.

Exercise. *Complete the following sentences:* The spring-operated —1— of a motion picture camera operates a rotating —2— and moves the —3— along in a series of jerks. Standard rate of taking motion pictures is —4— frames per second. The standard speed of exposure of a motion picture camera is —5— of a second. Pictures are —6— if the camera is moved in use. The film is reversed in —7— so that the film you take comes back to you as a positive. Images stay on the retina about —8— of a second.

Science activity. Obtain the help of someone who owns a camera in the community, and make a motion picture of some interesting activity at school. Follow directions given in the text.



A projector works in a way opposite that of a camera. The film is brightly lighted and its image is projected by convex lenses upon a screen.

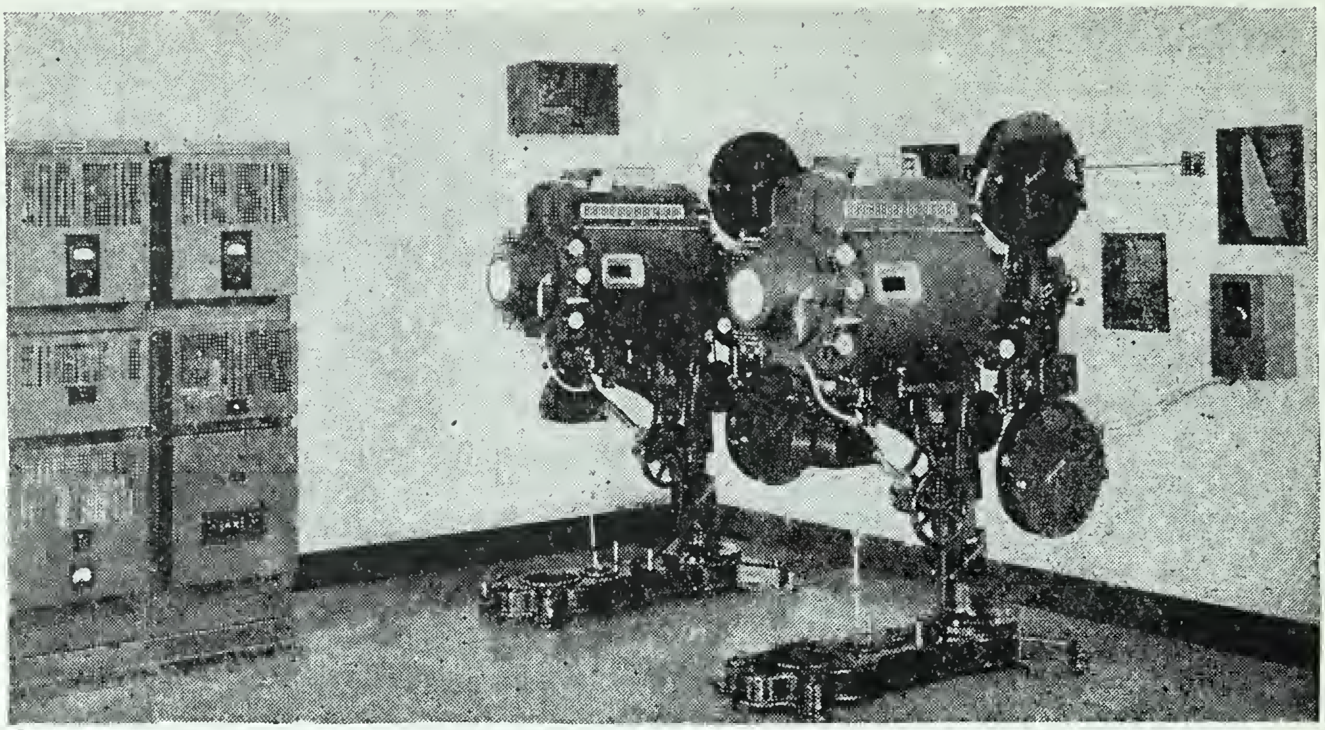
10. How are pictures projected?

There are several uses for projectors of pictures. The motion picture projector, the film strip projector, the glass slide projector, the postal card projector, the enlarger, and the film reader are all fundamentally the same machine, each adapted to the particular uses to which it is put.

How does a projector work? There are three parts to projectors. The first is a source of light, the second a device for holding and controlling the film, the third a set of lenses for projecting the picture.

There are two types of light sources in general use. The diffuser type consists of a box in which the lamp is placed, with an opal glass over the opening. The condenser type, which is much more efficient and gives sharper detail in the picture, consists of a set of lenses which concentrate the rays of light from a lamp on the film in parallel lines. A concave mirror behind the lamp also directs rays of light into the lenses. The special lamp used in the condenser system must be placed exactly in focus in relation to both the lenses and the mirror. Light passes through the film and is projected by the projection lens on the screen. The dark parts of the film are projected as shadows, the light parts as bright spots. The lens must be of good quality and quite large to permit enough light to pass through. A poor lens causes blurring. Projection lenses are made up of two or more convex lenses.

How does the motion picture projector work? The projector which shows movies in your school auditorium or local



Courtesy Western Electric Company

A motion-picture projection room includes two projectors. Cables from the projector carry current to the amplifiers (*left*) which control the loud-speakers. The picture is projected through the small window at the right.

theater is provided with a condenser type of light system. In large theaters arc lamps are used instead of Mazda lamps because they give a more brilliant source of light.

The projector is almost exactly the same as a camera in operation, except that the light passes through it in the opposite direction. The shutter is of the revolving type which moves past the opening of the lens and alternately darkens the screen and permits the beam of light to shine on the screen.

The film is mounted on a reel and led over a toothed sprocket which fits into the holes of the film. A loop is formed to provide slack. The film passes through guides and through a gate behind the lens. The shutter opens, the film is still, and the picture is shown on the screen. When the shutter is closed and the screen is dark, the film is moved and wound on another spool. The film must be wound back to the first spool before it is used again. Some projectors may be stopped to show single frames or run backward.

All except the least expensive projectors are operated by electric motors. The others are operated by hand cranks.

The "photograph" of sound is carried on the edge of sound

film and projected into a radio system to be changed into sound.

How do still-picture projectors work? The film strip projector has a condenser illuminator, equipped with a prefocused Mazda lamp. The film is placed on a spool and run through a gate provided with guides to hold the film in place. The film is moved by a hand-operated sprocket. Filmstrip is made on short lengths of motion picture film.

The most practical way to view color film is by projection. The pictures, taken with a 35-millimeter camera on motion picture color film, are developed into a colored positive and projected on a screen through a filmstrip or small slide projector.

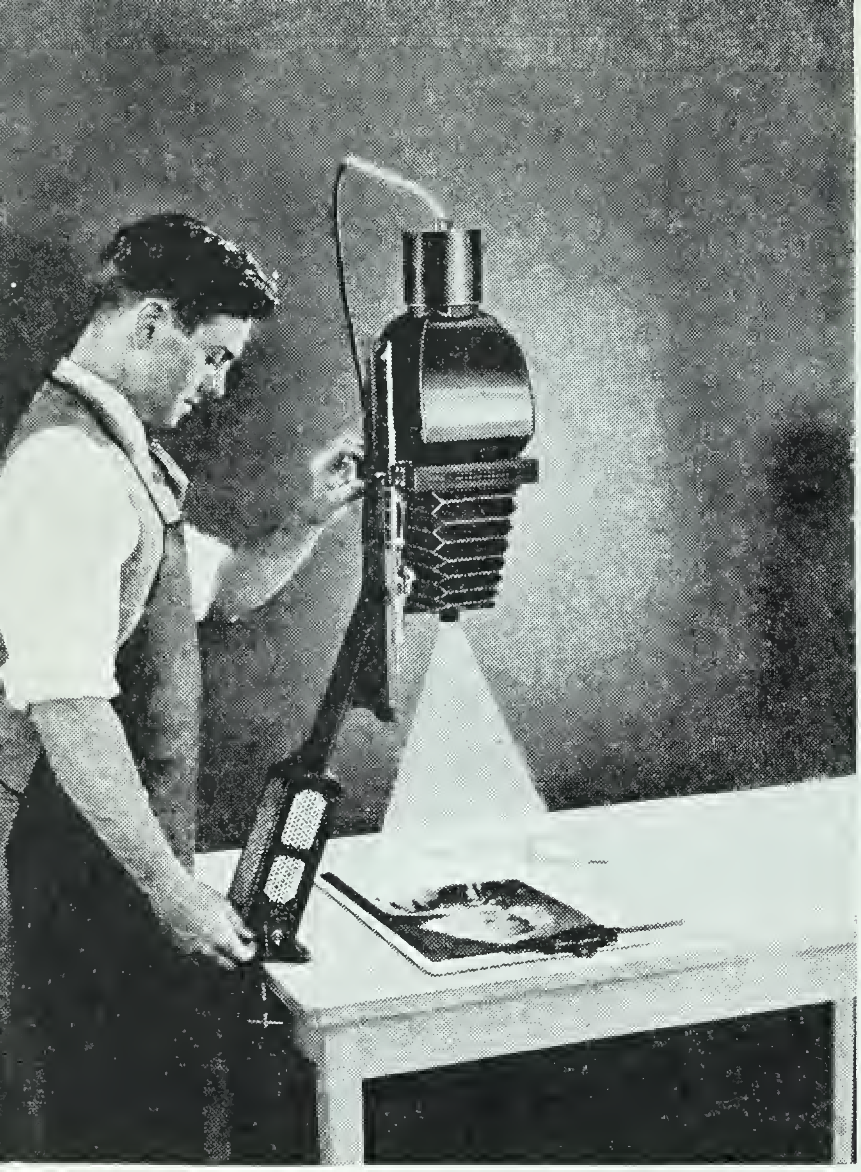
The glass slide projector is like the others, except that because the slide is larger, a larger lamp is required to illuminate the picture, and larger lenses are required. The photograph is printed on a piece of glass coated with an emulsion. To protect the emulsion from injury, another piece of glass is bound to the photograph with black cloth tape.

The slide is placed in a drawer-type holder, which slides into a slot behind the lens.

In the postal card projector light is reflected from the card through the projection lenses. Lamps are placed in the projector and screened from the lens. Usually two 500-watt lamps are used, set at 45 degrees to the card, one on each side of the lens. This strong illumination is required because the postal card absorbs from 80 to 90 per cent of the light. A total illumination of 1000 watts in a postal card projector is equal to about 200 watts in a film projector.

What is the enlarger? The enlarger is a projector, exactly the same in principle as the glass slide projector. Illumination is provided in the usual enlarger by a photoflood lamp, and a piece of opal glass is used to diffuse the light.

A negative is put into a slide made of two pieces of glass in a frame. The dull or emulsion side of the negative is turned toward the lens. The picture is projected upon a piece of white paper and brought into focus. When the arrangement of the picture seems pleasing, and it is properly focused, the enlarger light is turned out. Then by red light a piece of photographic enlarging paper is put in the place of the white



An enlarger projects an image of the negative on sensitive photographic paper. The box on top contains a lamp, the slide holds the film, and the lens projects an image.

paper. The enlarger light is turned on, and the picture is projected upon the sensitive paper. Exposure ranges from two seconds to one minute, the length of time depending upon the brightness of the light, the density of the negative, and the type of paper used. Enlarging paper is 500 to 1000 times faster than print paper.

The exposed paper is put into developer for 45 seconds or 1½ minutes, depending upon the type of paper used. It is then rinsed and fixed in the acid-hypo solution, washed, and dried just as a print is.

Most enlargers are mounted on a rod with the lens pointing down, and the paper is placed on the table. Many owners of cameras with removable backs use their cameras as enlargers. They make a light box and film holder, and use the camera for the lens and focusing device.

Enlarging permits one to select a small part of a negative to make a large picture. It also permits one to shade, brighten the light, and otherwise control the printing of the picture.

What are film readers? Many libraries are now recording books and magazine articles on film. An expensive camera of excellent quality using 35-millimeter film is used to photograph the books. Two pages are copied on a double frame, making a picture about 1 by 1¼ inches. An entire book may be photographed on a comparatively small roll of film. Rare and expensive books may be photographed to save them from handling. The cost of photographing one book is much less than the cost of printing it.

Courtesy International Research Corporation

In a film reader an image from a 35-millimeter film is projected upon a diffusing glass screen.

The print on the film positive is read in a film reader. This device is a small projector inside a box. It contains the usual lamp, lenses, and film holder. The print is projected upon a piece of ground glass which is mounted in the box itself. The film reader is a compact filmstrip projector.

Exercise. *Make a table by ruling your paper into five columns. Head the columns as follows:* TYPE OF PROJECTOR, LIGHT SOURCE, HOW LIGHT IS CONTROLLED, FILM HOLDER, LIGHT PROJECTED UPON. *Fill in the first column with the names of the projectors mentioned in this problem, and complete the table by describing the projectors with these words:* Mazda, photoflood, arc, condenser, diffuser, slide, guides and ratchets, screen, ground glass, photographic paper.

Science activities. 1) Make arrangements with an amateur photographer in your community to demonstrate for an interested group of pupils how enlargements are made.

2) Make an enlarger, following directions found in the reference book listed at the end of the unit.

3) Arrange to demonstrate before the class the construction and use of one of the projectors studied in this problem.

A Review of the Unit

Light is a form of radiant energy which travels through space in straight lines with a wave motion. White light is made up of waves varying in length from 400 to 700 light units. Violet light has the shortest wave length and the most energy. Red has the longest wave length and the least energy. White light may be separated into colors by the prism.

Light for indoor use should be brighter than 10 foot-candles, should be uniform in all parts of the room, and should be free from glare.

Light is reflected by surfaces through which it does not pass. Mirrors reflect light. Concave mirrors are used in headlights, in telescopes, and in magnifiers. Plane mirrors are used for viewing ourselves. Convex mirrors are used for rear-view automobile mirrors.

Light is refracted by passing through substances of differing densities. A convex lens focuses light rays, and is used to project images or magnify objects. Concave lenses are used to diminish size of objects.

Light is used in photography, for producing changes in the chemicals on film and paper, and for projecting images on screens.

An exercise in thinking

Match the principles and related ideas, according to the directions given in the review at the end of Unit I.

List of principles

A. Light is a form of radiant energy that travels in straight lines with a wave motion.

B. Color is dependent upon wave length, violet light having the shortest wave length and red the longest.

C. The shortest light waves have the most energy.

D. The angle of incidence equals the angle of reflection.

E. The intensity of light varies inversely in proportion to the square of the distance from the source.

F. Light is refracted or bent as it passes through substances of different densities.

G. A convex lens causes rays of light to be focused at a point.

H. Light may produce physical and chemical changes.

I. Light is given off by incandescent objects.

J. Light is given off as a result of electrical discharges through gases.

List of related ideas

1. Light changes the silver salts upon film when a picture is taken.
2. A sight meter produces an electric current when light shines on it.
3. We see motion pictures which are projected on a screen.
4. Hot carbon particles in a flame give off light.
5. Polaroid separates light in one plane from light in other planes.
6. Fluorescent lamps produce visible light by taking energy from ultraviolet light.
7. A single lamp in a room is a poor source of illumination.
8. Light falling upon a dark ceiling is changed to heat.
9. The objects in a mirror appear to be reversed.
10. We sight guns by use of light rays.
11. Northern lights appear in the sky where the air is thin and electricity is present.
12. Tungsten is used in electric lamps because it withstands high temperatures.
13. When light is reflected, its direction is changed by an object through which it does not pass.
14. A prism separates white light into colors.
15. A concave mirror focuses light rays.
16. The image in a pinhole camera is inverted.
17. Concave lenses are used in glasses to correct nearsightedness.
18. A red object absorbs wave lengths of from 400 to 600 light units.
19. We should sit relatively close to study lamps.
20. The neon lamp produces light without becoming hot.
21. The image inside the eye is formed on the nerves in the retina.
22. We must aim below an object in water if we wish to hit it.
23. Dust in the air diffuses light.
24. The vapor in a carbon arc gives off light.
25. Men in deserts sometimes see lakes where there are no lakes.
26. A black object absorbs all light which falls upon it.
27. Almost all glass is colored in the sense that it shuts out some kind of radiant energy.
28. We may use lenses as burning glasses.
29. When light loses energy, as in passing through space, it becomes redder.

30. The image formed upon the camera film is a real image.
31. Light fades many kinds of cloth.
32. We sometimes see rainbows in the sky when sun shines on raindrops.
33. A film reader is a kind of projector.
34. We must move the lens of a camera the right distance from the film before taking a picture.
35. A light with a brightness of 100 foot-candles at a distance of one foot gives a brightness of one foot-candle at 10 feet.
36. We use convex lenses to correct farsightedness.
37. A convex lens projects a real image.
38. Telescopes are often made of two or more lenses.
39. The biggest telescopes contain mirrors.
40. Light may be changed to heat.

Some things to explain

1. Why does a red filter cause a blue sky to look black in the finished print, while the white clouds look white?
2. What is the chief advantage of the new fluorescent lamp over the older Mazda lamp?
3. What are the three kinds of eyeglass lenses, and for what are they used?
4. Why can you take a picture in a shorter time with a camera with a lens than with a pinhole camera?
5. Find five different sources of glare in your schoolroom and work out ways of removing them.
6. Why do people sometimes suffer from snow blindness?
7. Can pictures be taken in the dark? Explain. Can you see in the dark? Why?
8. What would happen if you used a black filter on a camera?
9. What is a rainbow?
10. A scientist once said that if anyone sent him a lens of as poor a quality as the human eye, he would send it back. What did he mean?

Some good books to read

The Book of Knowledge
Collins, A. F., *Experimental Optics*
Compton's Pictured Encyclopedia
Eaton, Jeanette, *The Story of Light*
Faraday, Michael, *Chemical History of the Candle*
Fraprie, F. R. and Jordan, F. P., *Photographic Hints and Gadgets*
How to Make Good Pictures, Eastman Kodak Co.

Howell, J. W. and Schroeder, H., *History of the Incandescent Lamp*
Luckiesh, M., *Seeing and Human Welfare*
Stair, J. C., *The Lighting Book*
World Book Encyclopedia

Some interesting motion pictures

Light for Living. General Electric Company (*16 sound*)
Light of a Race. General Electric Company (*16 silent*)
Light Waves and Their Uses. Erpi (*16 sound*)
Illumination. Eastman (*16 silent*)
Behavior of Light. Eastman (*16 silent*)
Lenses. Eastman (*16 silent*)
Optical Instruments. Eastman (*16 silent*)
Eyes of Science. Bausch & Lomb (*16 silent*)
Mazda Lamp Manufacturing. General Electric Company (*16 silent*)
Mazda Lamp Preferred. General Electric Company (*16 sound*)

Some related lantern slides

Light. Keystone View Co.

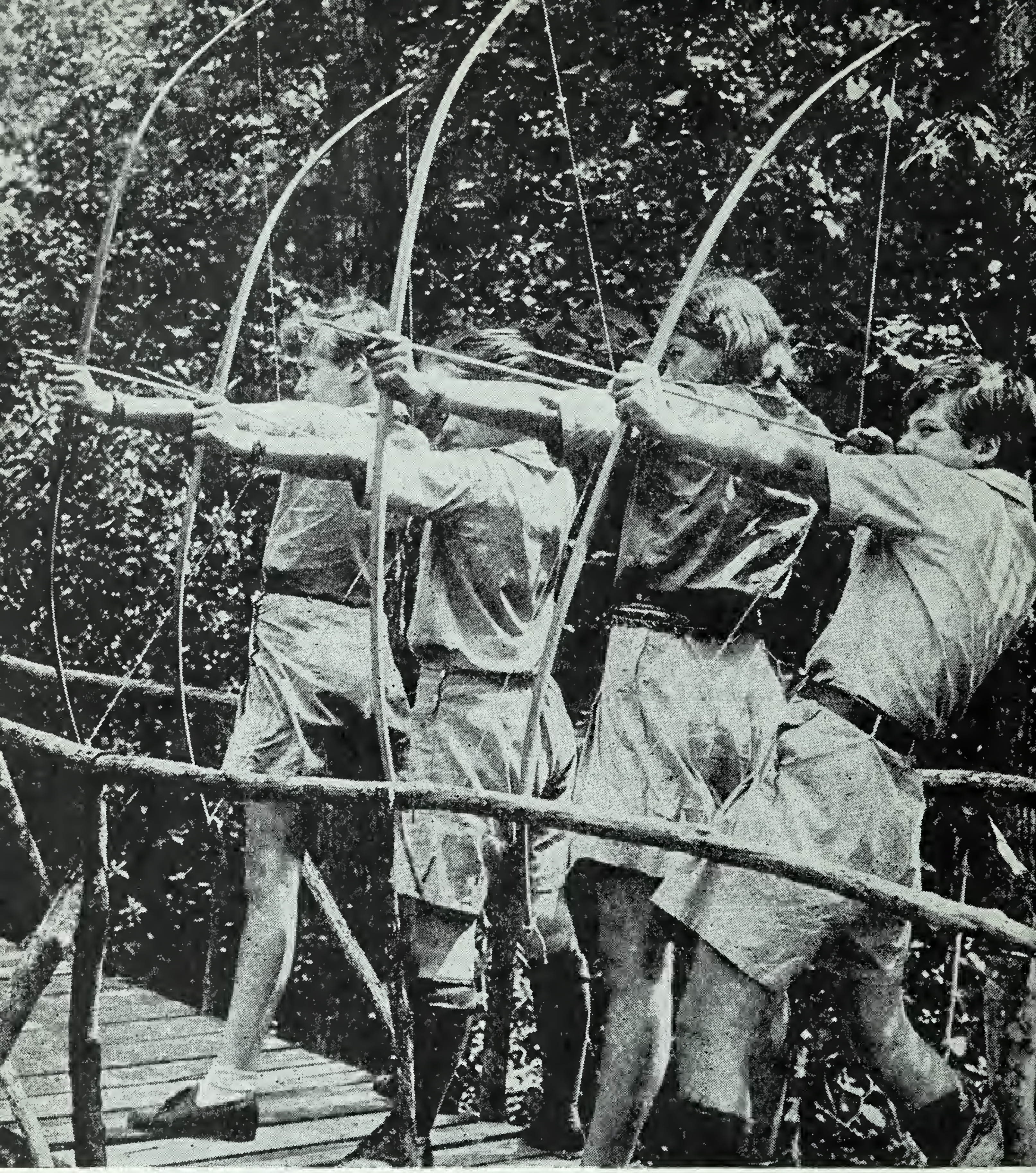


Photo by U. S. Forest Service

UNIT SIX

HOW IS ENERGY USED IN THE HUMAN BODY?

LIKE every other living organism, we depend upon food to provide the energy required to carry on all activities which make life possible.

If we lived under entirely natural conditions, as our primitive ancestors did, finding food might be less difficult in some respects than it is under civilized living. For civilized foods are greatly different from primitive foods. We take out and discard parts of the grains of wheat and the coarser leaves of vegetables. We throw away the broth of cooked vegetables and meats and discard other things that would provide needed food materials. Yet we do not want to return to primitive eating habits, because primitive foods are not of good flavor and are difficult to eat and to digest.

Instead, we must learn how to select from the great array of foods offered for sale the ones which we enjoy eating, and at the same time be careful to select those that protect our health by insuring a balanced diet. This is a simple enough matter if we know what body needs must be considered.

In order to understand what food the body needs, we should know what the body does with the food, and what organs have special needs. Do you believe that fish is a brain food? Do you think that meat causes high blood pressure? Do you eat special foods to make you fat or thin? Do you follow some special kind of diet—vegetable, fruit, or cereal—in the hope that it will make you healthier than if you eat an ordinary diet?

If you know the real needs of the body, you will see that these beliefs have no real foundation in bodily needs. You can sit down to a big meal of beefsteak, milk, bread and butter, salad, potatoes and gravy, carrots, and sliced peaches with even greater enjoyment if you know that such foods are the best you can select for health.

It is particularly important to know the true and scientific information available about food, because there is much unsound advice offered on every hand. Some of this advice is designed to sell foods for which there is no natural demand, some is offered by persons interested in selling some kind of "health system" at a profit to themselves, and some is offered because of ignorance. When you consider advice about food, consider the source of the advice.

Courtesy Hawaiian Pineapple Co., Ltd.

Pineapples are fruits, but they grow in a manner not common to our other fruits. They provide the same essential food materials found in fruits grown in this country.

1. What are the three big classes of foods?

There are two kinds of foods or nutrients [nū′trĭ · ĕnt] in our diets: those which we use in considerable amounts and those which we require in small amounts. Three classes of foods that we need in large quantities—the carbohydrates, the fats, and the proteins—are the nutrients which are digested and used up in the cells to provide energy and materials for growth.

What are carbohydrates? The carbohydrates are the sugars and starches. All chemicals in this group are closely related because they are made up of carbon, hydrogen, and oxygen in slightly differing proportions. The starch we eat becomes sugar when it is digested. Among the sugars are the simple sugars, such as corn, milk, and grape sugars, and the double sugars, of which cane and beet sugar are examples. Soon after digestion begins, the double sugars are converted into simple sugars. Sugars are easily detected by their taste.

We find starch in many common foods—in potatoes, bread, cake, gravy, beans and peas, apples, and tapioca.

Because the carbohydrate foods are relatively cheap and in general pleasant to eat, the diet of the average person is made up in a large part of these nutrients. Carbohydrates are chiefly of value in the body for supplying energy.

What are fats? Fats include such common materials as butter, salad oils, fat meat, nut oils, and cooking fats. They are chemical compounds of carbon, hydrogen, and oxygen but differ from the carbohydrates in their molecular structures. The carbohydrates may be converted into fat in the body—that is, if you eat more sugar than you need, it will

be stored in your body as fat instead of sugar. A certain amount of fat in the diet is needed to enable the body to use other foods, as well as to supply a concentrated energy food. There are at least two fat chemicals essential for health which the body cannot manufacture for itself. Fat is stored in the body and also serves as padding. Undernourished, lean people are irritable and nervous. Their nerves and bodies do not have enough padding for comfort.

What are proteins? Proteins differ from the other nutrients chemically in that they contain nitrogen, in addition to the three elements found in carbohydrates and fat. The protein foods are absolutely essential for growing children. Just how essential large amounts of protein may be for grownups is not known. Some tests indicate that too much protein may make people sluggish and may even reduce bodily condition favorable to long life. Other experiments indicate that meat eaters are healthier than vegetarians.

It is known certainly that some protein in the diet is essential to maintain life. There are many different kinds of proteins, which differ in their value to the body. The proteins found in milk, meat, eggs, and cheese are more complete and of more value to the body than are the incomplete proteins found in beans, peas, wheat, and gelatin.

The chemical compounds of which proteins are made are called amino acids. Twenty-one such chemicals are known, and most or all of them seem to provide some material needed for the body. The complete proteins contain a larger assortment of essential amino acids than do the incomplete proteins.

The proteins are perhaps as pleasant to eat as any other type of food. They are more expensive than carbohydrates or the cheaper fats, however.

How is value of food tested? The unscientific observer is likely to decide what foods should be included in his diet on grounds of taste, early training, or other unsound reasons.

Scientific testing of foods is an exceedingly difficult matter. Yet today our knowledge of foods is quite complete. The use of the white rat in these food tests has made it possible for people to test diets which no human subject would consent to try, for many diets thus tested are so unsatisfactory that they result in permanent injury to the animal.

The usual procedure is to select two groups of rats equal to each other in number, weight, sex, age, and inheritance. To one group a certain diet is fed, while the other group receives a diet exactly the same as that given to the first group, except that one experimental food is either added or left out. In this way, differences in weight, appearance, rate of growth, number of young produced, and other indications of vitality can be judged accurately. Sometimes, for the sake of checking the experiment, the experimental food is added to the diet of the less healthy group of rats to see if they can be improved in condition by use of the test food.

It is not entirely possible to conclude that any diet that is good for rats will be equally beneficial to human beings. Yet the similarities between the food requirements of rats and of men are much more numerous than are the differences. Even where differences seem to exist, the rat experiments at least open the way for experiments with diets for human beings.

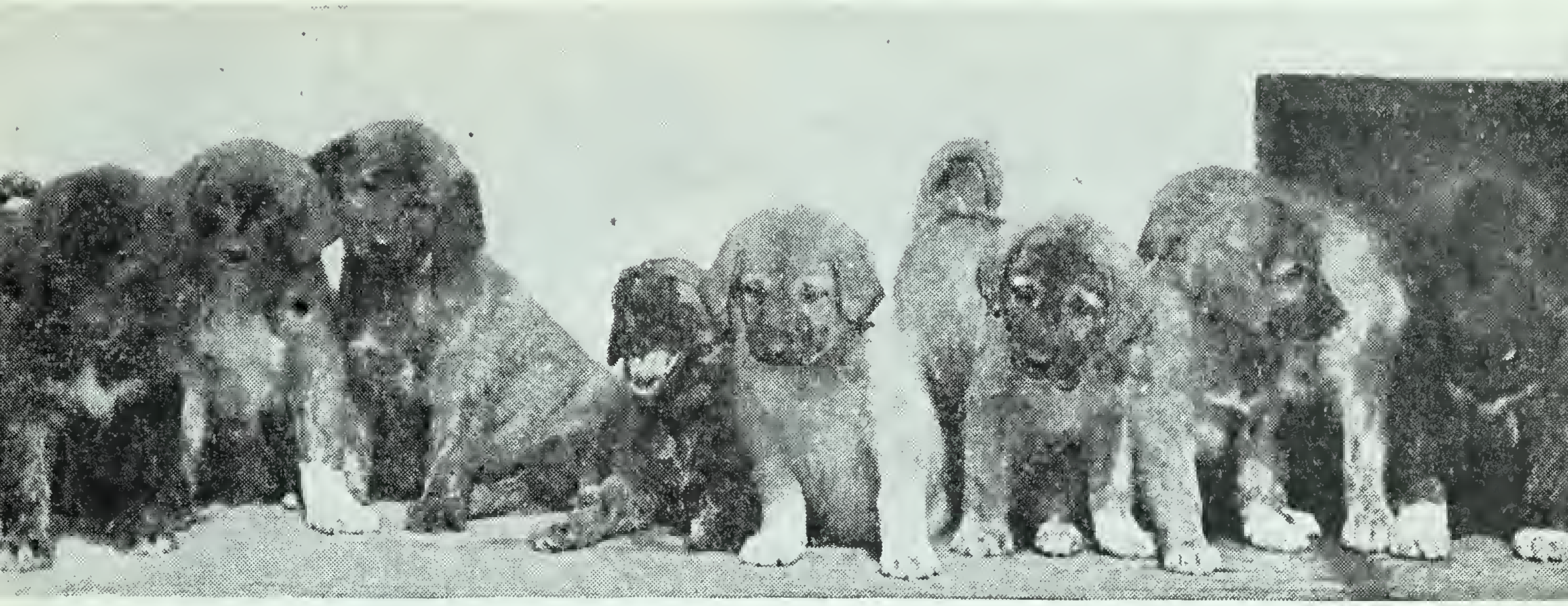
Another type of food testing is complex chemistry. To discover the exact proportions of various food nutrients in the common foods is a task that only a college-trained scientist can perform. There are many positions open in industry and in the government bureaus for food chemists.

The following table shows the nutrient content of a few of the common foods, as determined by chemical analysis (study of a material by breaking it into its parts).

FOODS	FAT (PER CENT)	CARBOHYDRATE (PER CENT)	PROTEIN (PER CENT)	MINERALS (PER CENT)	WATER (PER CENT)
Apples	0.5	14.2	0.4	0.3	84.6
Banana	0.6	22.0	1.3	0.8	75.3
Beef sirloin	19.1	0.0	19.0	1.0	61.3
Bread (white)	1.3	53.1	9.2	1.1	35.3
Egg	10.5	0.0	14.8	1.0	73.7
Milk	4.0	5.0	3.3	0.7	87.0
Potatoes (white)	0.1	18.4	2.2	1.0	78.3

DEMONSTRATION. HOW DO WE TEST FOODS?

What to use: Iodine, nitric acid, Fehling solutions A and B, ammonia, burner, ring stand, test tubes, foods, oil, corn meal, paper, metal disk.



Courtesy U. S. Bureau of Animal Industry

These pups were fed experimentally to test the value of various kinds of foods.

What to do: Test for starch. Prepare a thin paste by heating a little starch or white flour in water. Add to it two drops of iodine solution. Note the deep blue, almost black, color.

Test for sugar. Mix equal parts of the two Fehling solutions. To one-eighth of a test tube of a thin corn sirup add about a teaspoonful of Fehling solution, and heat until the mixture becomes a deep orange-red in color. Test rolled oats. Chew some rolled oats for some time, and test. Has chewing made a difference in the oats?

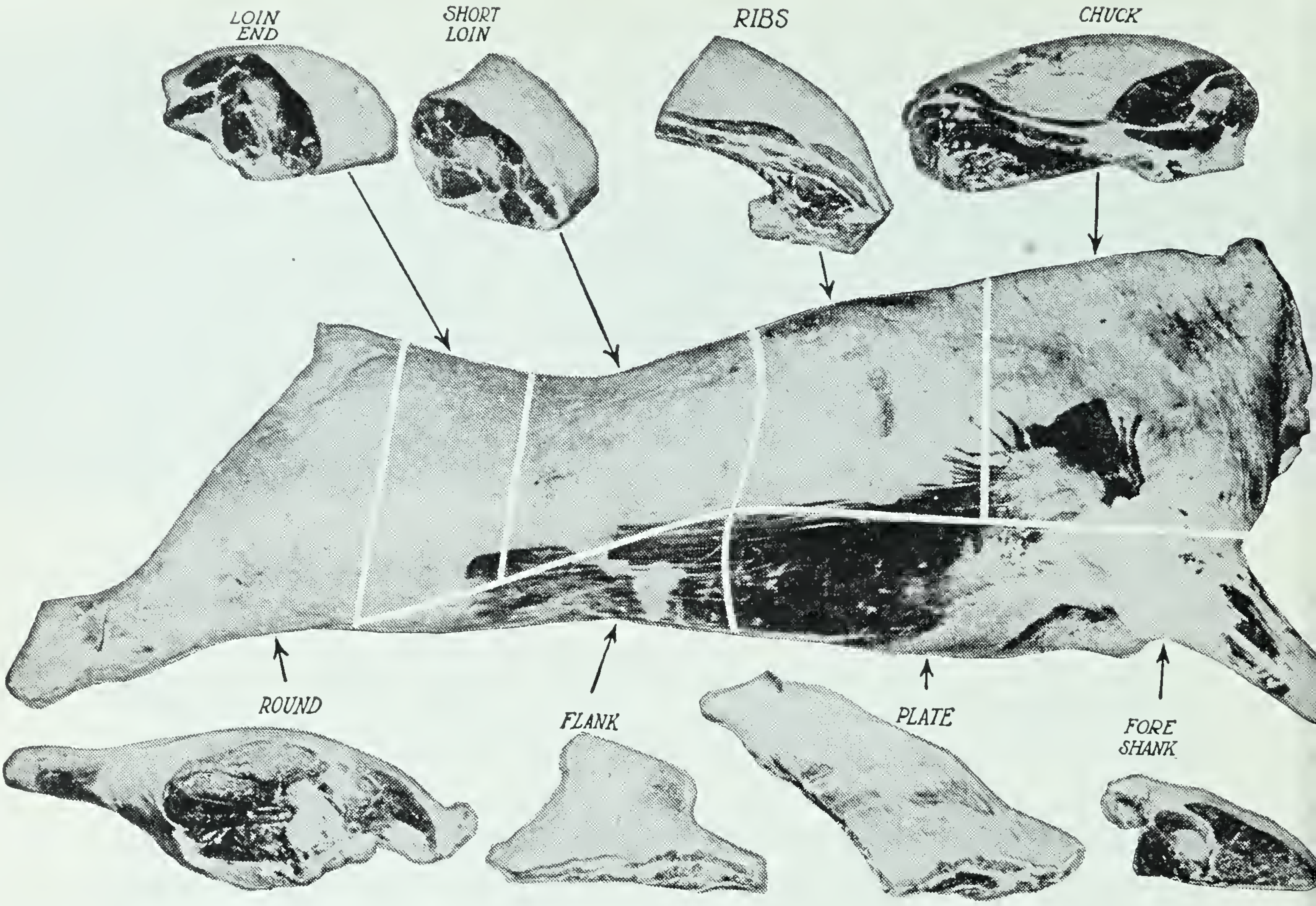
Test for protein. Place a small amount of egg white or milk in the test tube and add about one-sixth of a tube of nitric acid. Bring it to a boil. Carefully pour off the acid, cool the tube, and add one-eighth test tube of ammonia (ammonium hydroxide). The color should be first yellow, then orange.

Test for fat. Place ground-up corn or commercial corn meal upon a piece of paper, and place the paper upon the metal disk on the ring stand. Heat the metal very gently with the burner. After several minutes examine the paper for "grease spots" made by the corn meal.

What was observed: Make a table of the tests, including the name of the food, the purpose of the test, the chemicals used, and the changes observed.

What was learned: Summarize your observations.

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* fat, protein, carbohydrate, cane sugar, grape sugar, starch, amino-acid, iodine, Fehling solution, ammonia, nitric acid.



Courtesy Swift and Company

Cuts of meat are sold at different prices. The cut that sells for the highest price is tender and of good flavor. Another cut may have as much protein and sell at a lower price.

2. What are the sources of different classes of food?

Like other animals, we are unable to manufacture our own foods. We depend upon plants for our food, either directly by eating the plants or indirectly by eating animals which feed upon plants. To obtain the necessary amounts of the different classes of food, we take from natural sources a large number of foods intended originally for use by the plants and animals that produced them.

Where do we obtain proteins? Of the four food classes, protein is most essential for growth. As would be expected, we find protein in seeds—the food provided for the growth of young plants—and in eggs and milk—the food provided for the growth of immature animals. Each of these food sources contains enough protein to maintain life.

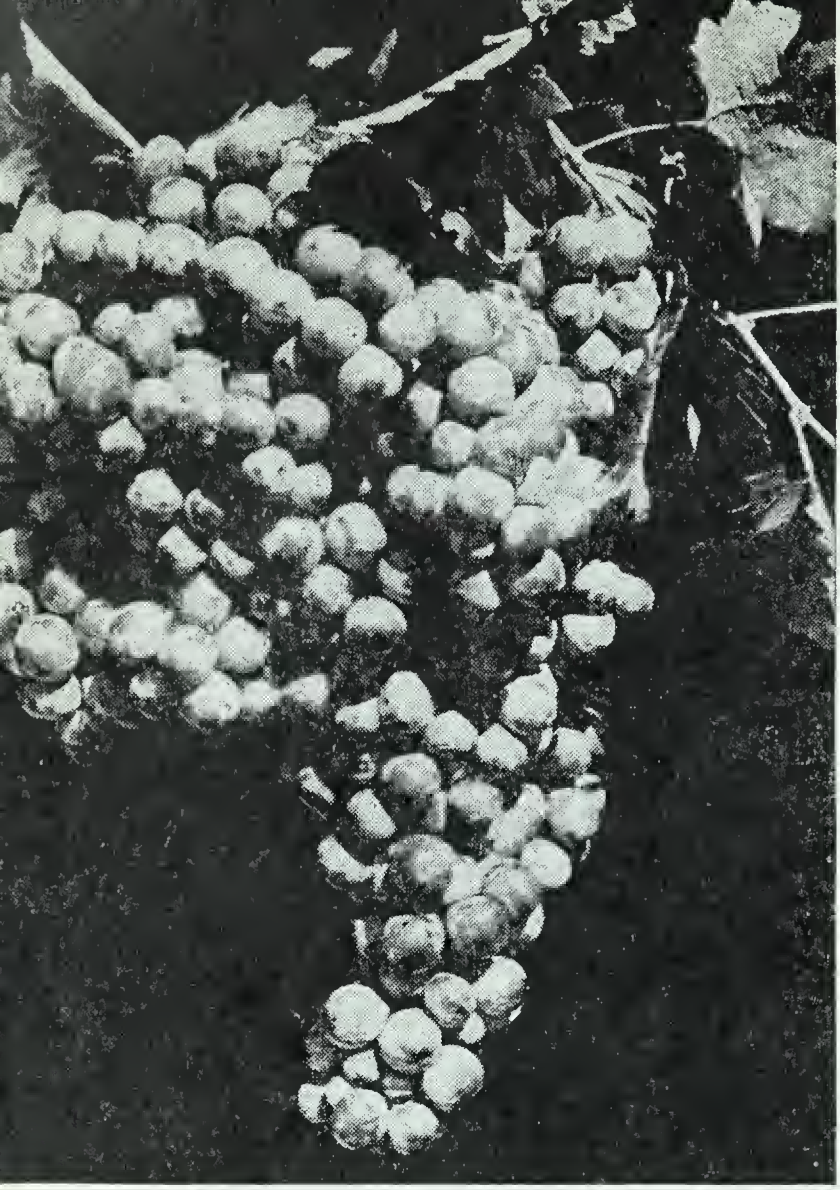
Meat is probably the most widely used of protein foods. Meat contains a complete type of protein, for it comes from living animals. Some primitive races, particularly in the polar regions, depend almost entirely upon meat for food. While some people believe that meat is not a desirable diet when eaten alone, explorers have seen little evidence of lack of health and vigor among Eskimos, who eat few vegetables or fruits. Meats include the flesh of cattle, pigs, horses, rabbits, chickens, geese, ducks, turkeys, deer, reindeer, buffalo, and many kinds of fish. Seals, polar bears, and even dogs are eaten for food. The so-called shellfish, or mollusks—clams, mussels, and oysters—provide protein foods. The Crustaceans—shrimps, crabs, and lobsters—are also used for meat.

Courtesy Hubbard Milling Company

The chief food made from seeds is bread. This flour-mill bakery tests flour by making loaves of bread and carefully examining them for texture, appearance, moisture content, and taste.

Seeds are not as good a source of protein as is meat. The best sources of protein from seeds are the legumes—beans, peas, lentils, soybeans, and cowpeas. Only three kinds of beans and two kinds of peas are used in this country. The soybean is an important source of protein in Asia. In fact the soybean is, next to rice, the most essential food of millions of people. Peanuts are valuable sources of proteins. Next to the proteins of the legumes, those of the grasses are of value. Wheat contains a protein called gluten which makes bread dough sticky enough to hold bubbles of gas. Most of the other grains contain only small quantities of protein. The proteins found in seeds are inadequate for the growth of children or for the maintenance of vigor of adults.

Among the most valuable and complete proteins are those obtained from milk and eggs. The milk of the cow, goat,



Grapes and all fruits contain carbohydrates, but they also contain needed minerals and vitamins.

sheep, mare, and donkey is used in various parts of the world as food. Many kinds of eggs are similarly used to provide protein. Because these proteins are complete, they are important articles in any balanced diet. A food which is complete enough to serve as the first food supply of a young animal is naturally rather complete.

Where do we obtain fats? Fats provide energy in concentrated form. There are two general sources of fats: fat of animals and the fat or oil of seeds.

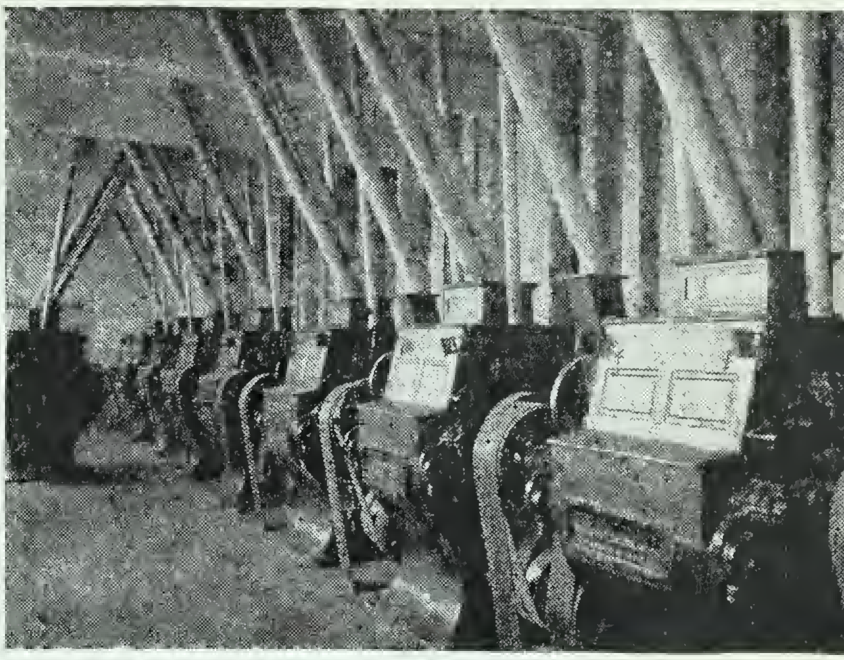
Fats, because of their concentrated form and because of their insolubility, are readily stored in seeds. Among the common vegetable oils are corn oil, cottonseed oil (after it has been chemically changed), coconut or palm oil, olive oil, and peanut oil. Oil is the chief food material found in nuts. An oil found in wheat germ contains a valuable vitamin. Almost all seeds contain fat. Rice, however, contains only a small amount of fat.

Animal fats are commonly used for food. Lard is the standard cooking fat and is desirable because it has a melting point well below body temperature. Beef tallow is more difficult to digest because it melts less readily than does lard. Butter, cream, and milk all contain fats, which are particularly valuable because they contain vitamins. The same is true of the oils extracted from fish livers. Egg yolks and cheese contain considerable amounts of fat.

Oleomargarine, which is an artificial butter, often is made of lard, cottonseed oil, coconut oil, and tallow. While it provides as much energy as does butter, it does not contain vitamins, unless they are artificially added.

You can see that in nature fat is stored either for use of an animal which requires considerable energy or to provide energy for growth of young.

What foods contain sugar? Sugar is used as an adaptation by those plants which have come to depend upon animals in various ways. Bees are attracted to flowers by nectar, which is a sugar solution. The bees make honey, which we take for our own use. Sweet fruits are an adaptation for spreading seeds because animals, which are attracted by the sugar in fruit, carry the seeds considerable distances before dropping them. As fruits ripen, their starch is changed to sugar.



Courtesy Hubbard Milling Company

These machines are flour grinders. The wheat flows into the grinders down the metal spouts, and the flour flows downward to sifting machines on the floor level.

Because it is readily soluble, sugar is easily carried in plants from leaves to roots and from roots to the growing part of the plant. We obtain much of our sugar from the stalks of cane, in which the sugar is held in the juice. Sugar is temporarily stored in the roots of certain beets, and we harvest the beets when the sugar content is highest. Sorghum corn is also used for making sugar.

Where do we obtain starch? Starch is a form in which food is often stored by a plant for its own use. Starch is also stored in seeds for the use of the young plant. Our chief starch foods are potatoes, flour, rice, cornstarch, root vegetables, and occasionally tapioca and sago.

The seeds contain starch because it is relatively insoluble and is useful for certain types of growth. The proportion of fat, starch, and protein in a seed seems to depend upon the special adaptations of a given plant, for there is considerable variation in the proportions of these three foods in seeds.

Starch is frequently stored in plants which go through a dormant or resting stage in winter and grow a second year.

The potato, which is properly an underground stem called a tuber, is an example of this type of storage. The starch is protected underground through the winter, and new plants form from the buds or eyes of the potato. Parsnips, beets, and carrots store starch in their roots.

Starch is stored to some extent in leaves. The fleshy leaf of the cabbage contains a small amount of starch. When the sun is shining upon leaves, they will react to a test for starch, indicating that it is manufactured in green leaves.

How do we prepare food for use? Few foods are fit for use as they are found in nature. Wheat must be ground, sifted, and stored for aging before it is usable. Corn is rolled into flakes and cooked; or it is ground into meal; or its starch is changed to sugar; or the oil is extracted before it is used for food. Meats are smoked to preserve or flavor them. Fat is rendered to produce lard. Much meat is made into sausages.

Most food is improved by cooking. The tough fibers of meat, the cell walls of starch grains, the fibers and skins of vegetables, and the flesh of fruits are softened by cooking until we can chew them into particles small enough to digest easily. Cooking destroys both kinds of harmful bacteria: those which cause decay and those which cause illness. Cooking also kills worms and other animal parasites in food. A very important advantage of cooking is the improvement in flavor it produces in most foods.

Some processing of food produces new products from food materials. Butter and cheese are made from milk. Oil is made from peanuts. Sugar is made from plant juices. Jellies and jams are made from fruit and sugar. And of course many products are made in the kitchen from such simple ingredients as sugar, flour, lard, eggs, and milk.

DEMONSTRATION. WHAT MATERIALS DO NATURAL FOODS CONTAIN?

What to use: Chemicals from preceding demonstration (page 290), foods that have not been processed.

What to do: Test several foods as indicated in Problem 1.

What was observed: Record your observations in a table.

What was learned: Can you make a general statement about foods found in fruits, seeds, and roots?

Exercise. *Make a table by ruling your paper into seven col-*

umns. Do not head the first column. Head the other columns as follows: SEEDS, FRUITS, JUICES, ROOTS AND TUBERS, MEATS, MILK AND EGGS. *In the first column write the following words:* Protein, Starch, Sugar, Fat, Types of processing. *Complete the table by filling in the blanks. You can use the words* "present" *or* "not present" *in most of the blanks.*

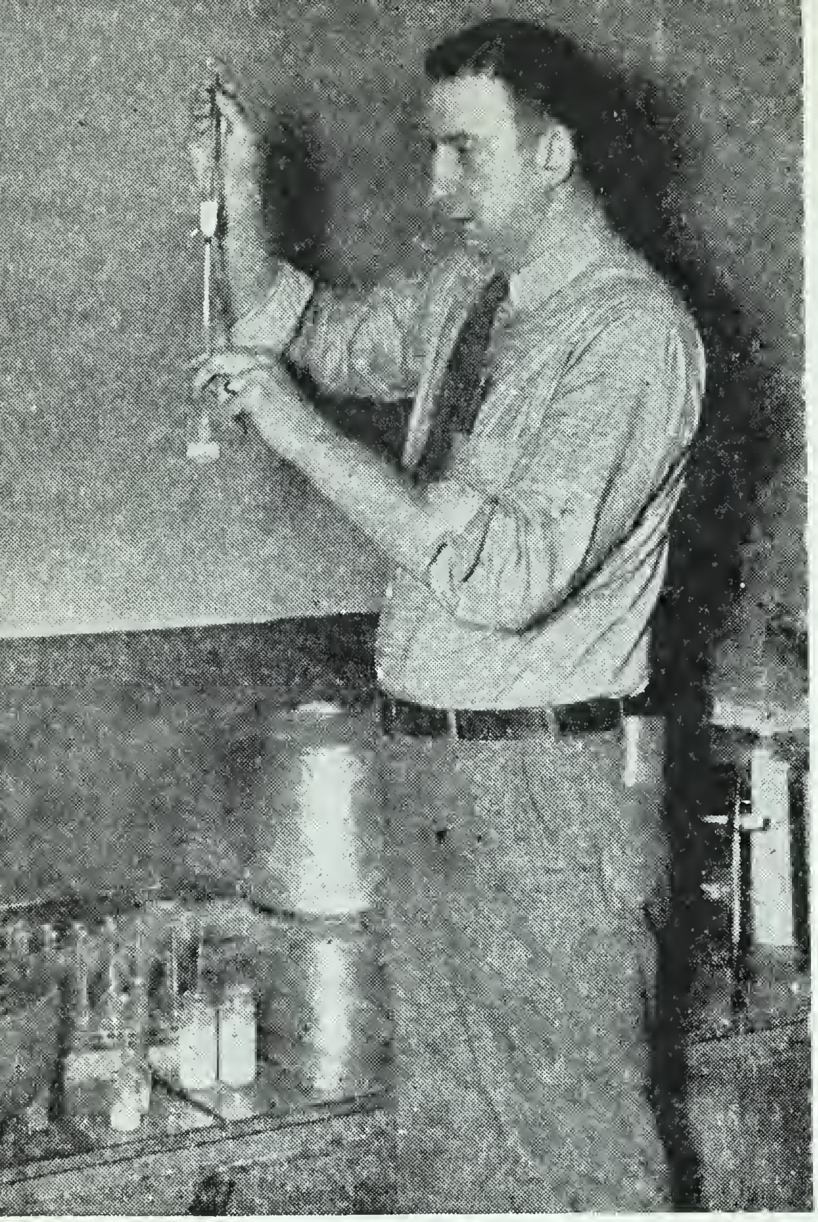
3. How do we measure the energy stored in foods?

Changes occurring in food in the body are somewhat similar to changes in wood burning in a stove. When wood burns, it unites with oxygen and gives off heat which is used to warm the room. In a similar way, food oxidizes in the body, uniting with oxygen and giving off heat which keeps the body warm. The products formed in each case as a result of oxidation are the same. In both the wood and the food the carbon burns to form carbon dioxide and the hydrogen burns to form water. The chief difference between the two processes lies in the fact that the wood in the stove burns rapidly, and this burning is accompanied by a flame. In the body the food oxidized slowly and there is no flame.

How is energy measured? As you know, the unit for measuring heat is called the calorie. The large calorie of food measurement equals 1000 small calories. It is the amount of heat required to raise the temperature of 1000 grams of water (about a quart) one degree centigrade, or about four pounds of water one degree Fahrenheit.

What are normal energy requirements? The amount of food needed by a person depends upon three things: age, weight, and amount of activity. A boy or girl 14 years of age requires more energy per pound than does anyone at a later age. If you are 14 years old, multiply your weight by 24 to find the number of calories you need; if you are 15, multiply by 22; if 16, multiply by 18.

One of the essential functions of food in the body is to provide energy. Unless this energy is released in activity, the food is stored as fat.



Courtesy the *Minneapolis Tribune*

The amount of energy in milk is dependent in part upon the butterfat content. Here milk is being measured into test bottles. The bottles are then rotated in a machine to separate fat and milk.

Older persons need less food in general, except those who do very hard work. A person playing football or doing any exceptionally severe muscular exercise uses almost 10 times as much energy as he does when sleeping. A woman who does little work may need as few as 1450 calories, while a large man sawing down trees in the cold all day may need as many as 6000 calories.

Among adults there is a close relationship between a person's weight and the number of calories his food provides. If a person's weight remains constant, then his diet provides the calories he needs. If he loses weight, his food does not provide enough calories, and the body oxidizes food stored in the body tissues. If a person gains weight, it indicates that the food he is eating is providing him with too many calories, for the extra food is stored as fat.

Scientific methods for reducing weight are based on the principle that a person's diet should contain fewer calories than his body needs. The extra calories needed are provided by the stored fat. Thus his weight is reduced.

However, weight alone is not a perfect guide to determine whether a person is getting the correct number of calories in his food, for there are other factors to be taken into account. And, of course, children should gain in weight because they are growing.

How much energy is found in different foods? Fats are the best of all foods for providing energy. They have

practically no other use in the body, except that some contain vitamins. A pound of pure fat supplies more than 4200 calories; a pound of protein or carbohydrate when dry contains less than 2000 calories. To get the right amount of energy from the various foods, it is estimated that about a pound of carbohydrates and a quarter of a pound each of fats and proteins supply the amount needed by an adult.

Courtesy U. S. Department of Agriculture

All these potatoes were produced by one plant. Because potatoes are cheap, they provide one of the most economical sources of energy.

The number of calories in an ordinary serving of food is shown for a number of common foods in the lists on pages 300 and 301. It takes only a small amount of butter, but a large amount of tomatoes, to supply 100 calories. In general, the more fat a food contains, the higher its fuel value. The more water a food contains, the less its fuel value. Rich sources of energy are cereals, dried seeds, butter, cheese, and meats.

What foods are cheapest to buy? It must be remembered that buying a sufficient quantity of calories is not enough to insure a good diet. If it were, one could live for a few cents a day by eating ground corn, which is the cheapest food produced in the world. However, one would starve rather soon on a diet of ground corn. To show the cost of certain foods per calorie, a list was taken to the market to obtain prices. It was found that one cent would buy the indicated quantities of each of the following foods:

	Calories		*Calories*
Sugar	325	Pork chops	40
Peanut butter	280	Oranges	40
Potatoes, white	200	Apples	40
Bread, white	160	Eggs	32
Butter	120	Roast beef	25
Cheese, American	85	Beefsteak	24
Milk, whole	55	Fresh fish	20
Bananas	45	Tomatoes, canned	12

This list is intended merely to give an idea of the great variation in the number of calories that one cent will buy. The position of foods on the list will vary as the prices change, and prices are not the same for all parts of the United States. Prices of many foods vary with the seasons.

Exercises. *Make a table by ruling your paper into four columns. Head the columns as follows:* QUANTITY; KIND OF FOOD; CALORIES PER QUANTITY; NO. OF CALORIES. 1) *To estimate how much energy you get from your food, make a complete list of your foods for a 24-hour period. Include candy bars, ice cream, and all between-meal foods, as well as your regular meals.*

2) *Under* QUANTITY *try to estimate foods in cupfuls, tablespoonfuls, or average servings, as indicated in the lists below. Why will your results be inaccurate?*

Protein Foods

	Calories		*Calories*
Milk, 1 cup	150	Pork chops, ¼ lb.	320
Egg, 1	70	Ham, ⅙ lb.	200
Buttermilk, 1 cup	80	Salmon, canned, 1 cup	200
Cheese, cream and Swiss, 1 oz.	125	Chicken, young, ¼ lb.	125
Cheese, cottage, 1 cup	250	Creamed codfish, 1 cup	200
Beefsteak, ¼ lb.	240	Halibut, ¼ lb.	135
Beef stew, 1 cup	300	Bologna, ⅛ lb.	125
Frankfurter, 1	135	Roast beef, ⅛ lb.	120

Carbohydrate Foods

Oatmeal, cooked, 1 cup	120	Potato, 1 av.	100
Rice, cooked, 1 cup	135	Cup custard, 1	250
Corn and wheat flakes, serving	75	Ice cream, vanilla, 1 cup	360
Cracker, soda, 1	25	Jelly, large serving	100
Bread, large slice	100	Pie, mince, etc.	375
Doughnut, 1	150	Pie, fruit, av. serving	350
Biscuit, cream, 1	200	Candy, 1 lb.	1400-2800
Cake, av. helping	200	Sugar, 1 tbsp.	60
Potato, sweet, 1 av.	200	Baked beans, 1 cup	400

Fat Foods

Peanuts, 35 (1 oz.)	280	Cream, 1 tbsp.	25
Mayonnaise, 1 tbsp.	100	Cocoa, 1 cup	225
French dressing, 1 tbsp.	70	Fats and oils, 1 tbsp.	110

Fruits and Vegetables

Apple sauce, 1 cup	200	Cabbage, boiled, 1 cup	80
Apricots, canned, 1 cup	180	Beans, string, 1 cup	90
Orange juice, 1 cup	100	Carrots, 1 cup	80
Orange, 1 av.	80	Cauliflower, 1 cup	70
Apple, raw, 1 large	100	Lettuce, 1 serving	5
Stewed fruits, 1 cup	100-150	Asparagus, 1 cup	20
Banana, 1 av.	100	Spinach, 1 cup	40
Date, 1 av.	25	Radish, 1 av.	10
Grapes, raw, 1 cup	150	Beets, 1 cup	80

Miscellaneous

Soup, tomato, 1 cup	75	Sandwich, ham, 1	300
Soup, bean, 1 cup	250	Sandwich, fried egg, 1	350
Consomme, 1 cup	30	Sandwich, tomato, 1	220
Pickles, 1 av.	10	Gravy, brown, 1 tbsp.	15

Science activities. 1) Count the calories in average-size helpings of meals taken from a newspaper menu to see whether it is well planned from this point of view.

2) Prepare a diet for one week for a high school girl who is 20 pounds overweight (1200 to 1500 calories), being very careful to provide enough minerals, vitamins, and proper balance.

3) Provide a diet for a high school boy who wishes to gain weight to make the football team (3500 to 4000 calories), keeping the matter of balance in mind. Plan one week's menu.

4. Why are vitamins needed by the body?

Vitamins perform an unusual work, for they show their importance most in their absence. A person who eats a complete diet—that is, one supplying all the necessary foods—may never need to know anything about vitamins at all, for a complete diet is protection against diseases caused by lack of vitamins. Lacking a complete diet, one may develop eye disease, crooked bones, strange illnesses, loosening of the teeth, or paralysis, depending upon what type of foods are lacking in the diet. The vitamins, which by their presence prevent these difficulties, are substances found in certain foods.

The first vitamin was discovered more than 30 years ago. Since that time a number of others have been found. These have been named after the letters of the alphabet, A, B, C, etc.

Courtesy Nash Kelvinator Corporation

For between-meal eating, vegetables and fruits are far better than candy and other sweets. The wise mother has a well-stocked refrigerator and gives the child food instead of money for sweets.

Their characteristics have been learned by the effect their presence or absence has on the growth of animals.

To test the effects of vitamins, two groups of white rats are generally used. One group is given a diet deficient in vitamins, while the second group is given enough vitamins for a normal diet. Of course people cannot be used like rats in experiments, yet observations that have been made of the food habits of sick people indicate that the effect of vitamins on people is similar to that on rats.

Vitamins may also be tested by laboratory methods. Since most of the vitamins have now been separated into pure chemicals, their properties can be determined. Vitamin B_1, C, and D are white solids, the first two soluble in water.

What is vitamin A? Vitamin A is a builder of general body health. Lack of vitamin A also produces an eye disease. People who can see well in the daytime but are blind at night usually recover from the night blindness if given vitamin A. A diet rich in vitamin A is particularly important for those who drive much at night.

Vitamin A is found in many common foods, some of the best sources being eggs, butter, cream cheese, carrots, green vegetables, and fruits. The more green or yellow color a food contains, the more likely it is to contain materials from which the body makes vitamin A. The green outer leaves of lettuce contain 30 times as much vitamin A as do the pale inner leaves. Cod-liver oil is also rich in vitamin A.

What is the complex vitamin B group? What was formerly called vitamin B is now known to be made of nine or more

vitamins, including B_1 (also called F) and B_2 (also called G). Lack of B_1 may cause the disease known as beriberi, common in the Far East. Paralysis, loss of weight, soreness of the muscles, and general illness are symptoms of the disease. Lack of B_1 also causes loss of appetite. Users of alcohol in large amounts are usually deficient in vitamin B_1. This vitamin is abundant in the coverings of grains, the part that is removed from the whole kernels when making white flour and by polishing rice. The vitamin is abundant in whole wheat flour and rough rice. It is also found in fruits, green vegetables, yeast, and nuts. B_1 is perhaps the most essential of all vitamin foods.

Lack of one or more of the vitamin B group is the cause of the disease pellagra. This disease is quite common among the poorer people in the southern parts of the United States who live on the corn bread-bacon-molasses diet. It is estimated that 200,000 people at any given time are suffering serious ill effects from this disease. The disease may show itself in eruptions on the skin and in disturbances of the digestive and nervous systems. It can

Courtesy U. S. Bureau of Home Economics

The rat at the top had a normal diet. The second rat lacked vitamin A. The third rat lacked B_1 and suffers paralysis. The guinea pig lacked vitamin C and has scurvy and sore joints. The two rats with crooked legs and short bodies lacked vitamin D. The last rat, which is losing its hair, lacked vitamin G, which is one of the vitamin B group.

Courtesy U. S. Bureau of Home Economics

These foods contain vitamin D; but since there are so few foods that contain this vitamin it is particularly important for boys and girls to play in the sunshine, as the sun's rays furnish the body with vitamin D. It is not necessary, however, to obtain a deep tan.

be prevented by including in the diet eggs, meat, milk, and a variety of fresh fruits and vegetables, all of which contain vitamin B_1. It may be cured by use of brewer yeast tablets.

What is vitamin C? Vitamin C is known to prevent scurvy, a very unpleasant and dangerous disease which causes loosening of the teeth and changes in the gums. This vitamin helps to form and maintain the teeth properly. Oranges and tomatoes are the best sources of this vitamin, although it is found in most fresh fruits and vegetables. A half cup of orange juice, or a cup of tomato juice supplies the smallest safe amount of vitamin C for one day's needs for a 120-pound person. There is good evidence that in very young children the most important factors in growth of strong teeth are sufficient vitamins, especially C and D, and minerals.

What is vitamin D? Absence of vitamin D causes rickets, a disease of the bones. Bowlegs, crooked feet, uneven growth of ribs, knock-knees, crooked teeth, and poor growth of all the bones of the body result from lack of vitamin D. Vitamin D also speeds up the growth of broken and injured bones.

Vitamin D may be supplied to the body in two ways. The body can make the vitamin when exposed to the ultraviolet

Courtesy U. S. Department of Agriculture

Fresh vegetables contain all the vitamins except D. Most of the vitamin B found in potatoes is in the skin. Canning vegetables may destroy vitamin C, if they are exposed to air in cooking.

rays of the sun. It is therefore called the sunshine vitamin. The vitamin can also be supplied in our foods, but it is not as abundant as are the other vitamins. The largest amounts of this vitamin are found in the oil extracted from the livers of certain fish, such as cod and halibut. Among our foods the best sources of vitamin D are milk, fish, liver, eggs, and butter.

Experiments have shown that by feeding cod-liver oil to cows the amount of vitamins D and A found in the milk fat was greatly increased. Vitamin D can also be supplied to milk by letting it run through a beam of strong ultraviolet light.

What is vitamin E? Vitamin E affects the ability to reproduce. It is an important part of the royal jelly fed to queen bees to keep up their ability to produce eggs. It is found in many foods, and there is little evidence that it is normally lacking in human diets.

How does cooking affect vitamins? The effect of cooking is not the same on all vitamins. Vitamin C is the most sensitive and is more easily destroyed than are the other vitamins.

Cooking cabbage destroys nearly 90 per cent of the vitamin C present in fresh cabbage. However, canned tomatoes contain almost as much vitamin C as the fresh tomatoes. The reason this vitamin is not destroyed in canning seems to be that the tomatoes are exposed to the air for only a short time while they are being heated.

Fresh fruits and vegetables contain a large amount of vitamin C. The drying of fruits and vegetables destroys much of this vitamin.

Vitamins A, B_1, and B_2 are not greatly affected by the heat used in ordinary cooking. The use of soda to soften cooking water destroys vitamins B_1 and B_2. Vegetables should not be cooked in pressure cookers, but should be cooked in boiling water which is free of oxygen. The water should be boiling vigorously when leafy vegetables are dropped into it in order to save as much vitamin C as possible.

Are vitamins important in the normal diet? People who have little money to spend upon food too often try to omit from the diet the foods containing vitamins, especially fruits, milk, eggs, meat, and green vegetables. Then too, many children are so badly trained in their food habits that they do not care to eat these foods and, as a result, remain sickly and underweight. They are more likely to fall victim to diseases than are other children. Cooks too often throw away the colored leaves of lettuce and cabbage and save the less valuable inner leaves.

It is obvious that a person may eat enough calories and still starve to death. Gelatin, cornstarch, and lard will supply all the calories one needs, yet they make an absolutely inadequate diet. Dark bread, milk, and cabbage make a much better diet, even though they contain fewer calories per pound than the first three foods.

Should we follow vitamin fads? Because vitamins have certain values in the diet, quacks who sell foods, medicines, and cosmetics are quick to take advantage of public ignorance concerning their true use. Vitamins are advertised as being essential parts of cosmetics, cold creams, health foods, patent medicines, and many other materials in which they are not naturally found. But vitamins have little value except in foods, or in medicines prescribed by a doctor.

Filmstrip: Food makes a difference. U.S.D.A.

Exercise. *Complete the following sentences:* Vitamin C prevents —1—. Vitamin —2— gives resistance to disease. Vitamin B_1 prevents —3—. Vitamin —4— is the only one that can be made by the body. Vitamin —5— prevents pellagra. Vitamin D prevents —6—. Vitamin —7— is known as the sunshine vitamin. —8— are animals most commonly used in experiments with vitamins. The vitamin most easily destroyed by cooking is —9—.

5. What minerals are needed in an adequate diet?

Minerals are needed in the body for two purposes. They constitute the major portion of the bones and teeth and also are essential in small amounts for providing chemicals needed for growth of the cells. These minerals must be taken into the body in foods, for in their pure state practically none of them are useful. Some are actually poisonous if taken in concentrated form.

Why do we need calcium? Calcium, the element found in lime, is the mineral used most abundantly in the body. The chemical of which bones and teeth are chiefly composed is calcium phosphate. Every person needs calcium, but it is especially important for children and for mothers during the time their babies are developing. Calcium cannot be used in the body unless there is also present an adequate amount of vitamin D. Lack of sufficient lime in the diet causes poorly formed teeth, rickets, tooth decay, and in extreme cases convulsions and loss of bodily control.

The best source of calcium in the diet is milk, for it is easy for most people to use large amounts of milk. Buttermilk and cheese also supply calcium. Other good sources of calcium are the green leafy vegetables—cabbage, broccoli, chard, mustard and turnip greens. There is some calcium in most vegetables.

Why do we need phosphorus? Phosphorus is usually used in the body combination with calcium, although phosphorus is also needed for the growth of cells. Although more phosphorus than calcium is used up in the body daily in the processes of living, it is easier to get enough phosphorus than

Courtesy U. S. Department of Agriculture

The source of all minerals is the soil.

enough calcium. The foods which contain calcium also contain phosphorus. In addition, beans, lean meats, peas, eggs, soybeans, most nuts, and most fish contain phosphorus.

Why do we need iron? The chief uses of iron are to form the red chemical in the blood cells and to provide iron for the growth of body cells. Each day about a trillion new blood cells are formed in the body, and each needs its tiny portion of iron. An inadequate supply of iron or improper usage of iron in the body results in a disease called anemia [ȧ·nē′mĭ·ȧ]. The disease results in lack of vigor, paleness, and low resistance to infectious diseases. Sometimes anemia may be fatal.

Lean meat, egg yolks, leafy vegetables, liver, and beans are good sources of iron. Whole grains and a few fruits contain useful amounts of iron. Milk contains so little iron that it is of no value in providing iron in the diet.

Why do we need copper? Copper is essential for proper growth, but it is required in such small amounts and found in such a variety of foods that it is likely to be present in sufficient amounts in any normal diet.

Why do we need iodine? Iodine in the diet is essential for regulating the growth of children and the use of energy in the bodies of adults. Iodine is used in the body by the thyroid gland, a spongy organ situated in front of the windpipe. Lack of iodine or improper use of iodine in the body causes goiter, a disease of the thyroid gland. Upsets of this gland may make a person nervous and irritable, or inactive and fat.

Iodine is found in foods grown near the sea but hardly at all in foods grown inland. Sea foods are the best source of iodine. In most regions far removed from the ocean a small amount of an iodine compound is added to table salt.

Courtesy U. S. Soil Conservation Service

Erosion may remove from the soil so many soluble minerals that people of the region may be undernourished from lack of proper mineral foods.

What are trace elements? Certain elements, needed by the body in such small amounts that it is difficult to determine just how much is needed, are found in traces in the human body. Among these elements are manganese, which is related to bone growth and reproduction; cobalt, which is related to production of red corpuscles; magnesium, which is related to growth; bromine, which is concentrated in a gland within the skull; and many others.

How much mineral do we need? The body contains enough calcium for about seven pounds of lime, enough phosphorus to make about two pounds, enough sodium to make a shaker of salt, enough iodine to make a tenth of a drop of tincture of iodine. The rest of the minerals are found in amounts too small for common measures. Yet in terms of diet these are large amounts, for the amounts found in food are also mere traces. It is necessary for a child to drink about 100 gallons of milk a year to get as much calcium as he needs.

How can we cook foods to save minerals? Most of the minerals found in foods are soluble in water. If the food is boiled in a large amount of water for a long time and the

water is then thrown away, most of these minerals may be lost. The correct cooking method, of course, is to use as little water as possible, cooking the vegetables partly in steam in a closed kettle. Vegetables should be cooked only until they are tender. If meat is to be cooked with green vegetables, the meat should be almost entirely cooked before vegetables are added. Vegetables cooked with roasts of meat usually retain their minerals. In any event, the water should be served with the vegetables and eaten. Excess water may be used to add to gravy.

Are there poisonous minerals? There are a number of elements which even in small amounts are poisonous. Among these are mercury, arsenic, lead, selenium, and copper. Mercury may be inhaled from vapors from broken lamps and thermometers or from any other source of liquid mercury. Lead and arsenic are most commonly taken into the body by eating food contaminated by Paris green and arsenate of lead sprays. These sprays are commonly used on fruits and sometimes on leafy vegetables. Rigid enforcement of laws limiting use of these sprays is desirable but, so far, has not been demanded by the public. In the meantime, do not eat apples or pears without peeling them, particularly around the stem and blossom ends. Use cabbage from a producer who does not use these sprays, if you can find such a person in your community.

Selenium is found in the soil of certain dry regions just east of the Rocky Mountains. Cattle in these regions sometimes die from eating vegetation grown in poisoned soil. It may be necessary to abandon such soils for production of food. There is no way by which you can know whether or not flour you buy came from wheat grown in these areas.

Copper is sometimes introduced into food by contamination from cooking containers, but rarely in dangerous amounts.

How can we conserve soil minerals? Since soil is used to support dense populations for generation after generation and since minerals are dissolved from the soil by water, each year there is less and less mineral left in the soil to enrich plant food. People living in regions where the soil is poorest live upon the products of that soil because they can afford no other food. They often lack so many necessary foods that

a shortage of minerals is probably not the only cause of their lack of vitality. Yet it is entirely probable that food from better soil would lead to improved health of many individuals in these depleted regions.

Scientific agriculture rebuilds soil as it is used. This is the only way to insure an adequate supply of minerals in our diets in the future.

Demonstration. What Foods Contain Minerals?

What to use: Bunsen burner; crucible; ring stand; beans, wheat, or cocoa.

What to do: At the beginning of the period put about a teaspoonful of one of the foods in the crucible, and heat it as hot as possible until nothing is left but a white ash.

What was observed: How much ash did the food contain?

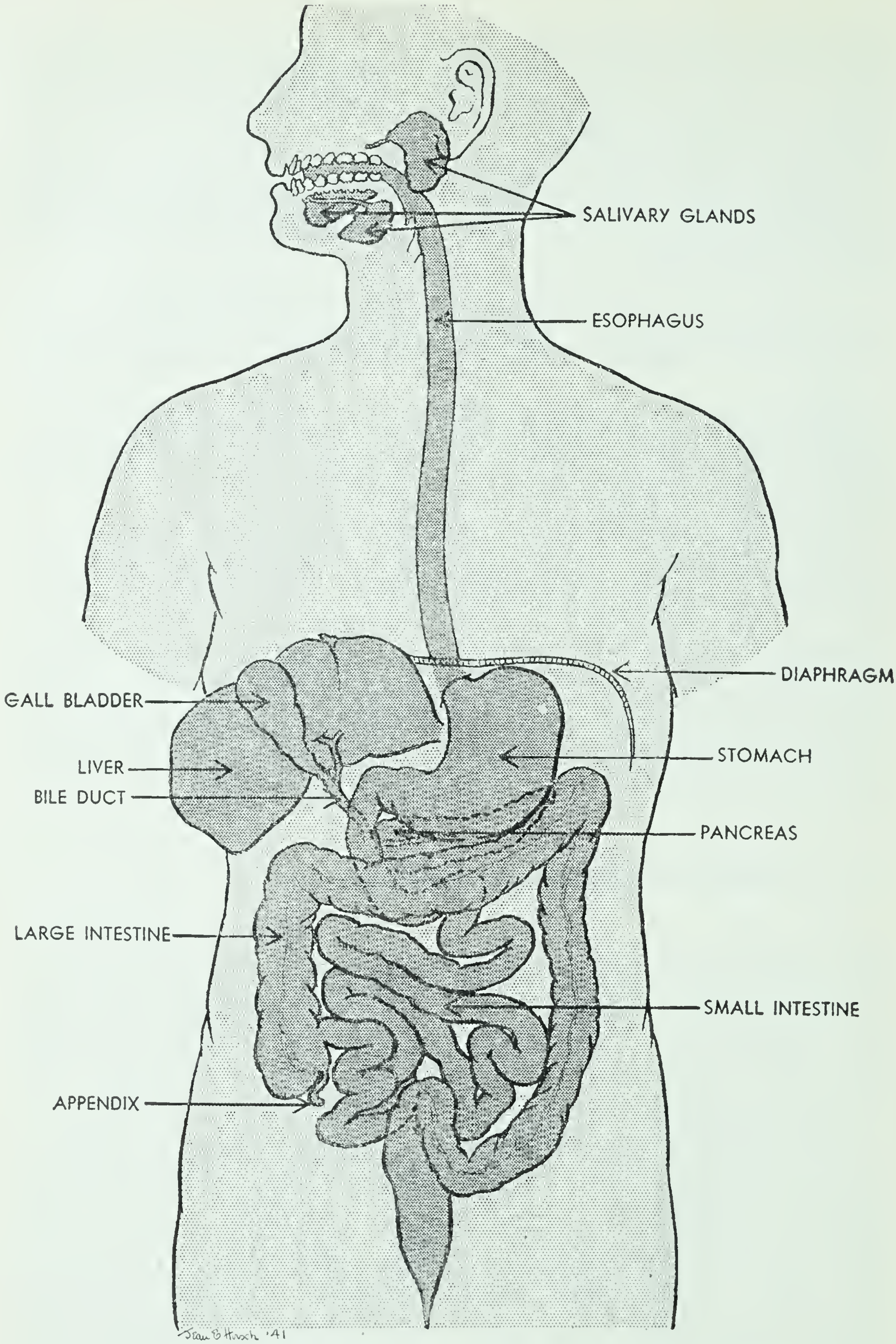
What was learned: Does food contain mineral? Do you know what minerals are found in the ash?

Exercise. *Make a table by ruling your paper into four columns. Head the columns as follows:* MINERAL, FOUND IN, USE IN BODY, HARM RESULTING FROM ABSENCE. *Fill out the table by writing into the columns the names of minerals mentioned in this problem, a few foods containing them, and other information.*

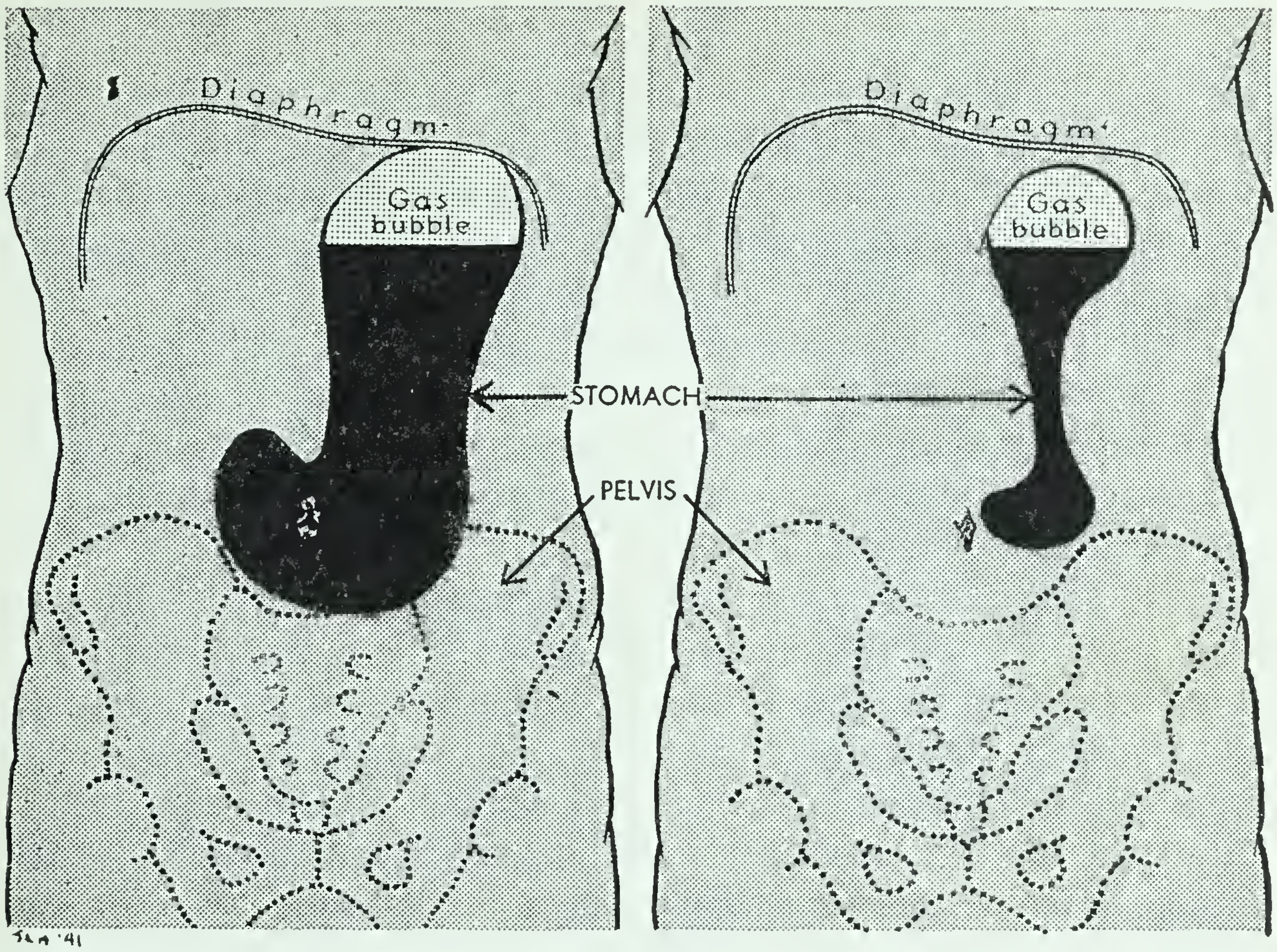
6. How do we digest our foods?

Food taken into the body is useless until it reaches the cells. The entire process of changing the food from a group of fats, proteins, carbohydrates, and other materials into soluble substances which can be absorbed by the cells is called digestion. After food is digested, it must be carried to the cells and combined with oxygen or stored for future use.

What is the digestive system? Digestion is accomplished in a set of organs called the digestive system. The digestive system consists of the alimentary canal, which is a long tube extending entirely through the body, and other organs along the canal. These other organs produce various chemicals which act upon the food. Such chemical-producing organs are called glands. The alimentary canal consists of the mouth, a food tube to the stomach, the stomach, the small intestine, and the large intestine. The large intestine really does very



The chief organs of the digestive system are shown in this diagram. They are spread out somewhat in order to show each one. Only the pancreas is hidden behind other organs.



These drawings are made from X rays of the stomach when it is full and when it is empty. The stomach extends lower in the body than many people think. The bubble of gas is almost always present.

little work properly called digestion. The entire alimentary canal in a grown-up person is from 25 to 30 feet in length, with the small intestine making up about 20 feet of the total. The large intestine is usually about five feet in length. The intestines are coiled and twisted inside the lower part of the body cavity. The words "small" and "large" refer to diameter, not length.

The glands which produce digestive juices are the salivary gland of the mouth, the gastric gland of the stomach, the intestinal glands of the small intestines, and the pancreas [păn′krē·ăs], which pours its fluid into the small intestine.

What food is digested in the mouth? Most of the change of digestion is chemical, but in the mouth a very important physical change occurs, that is, the chewing and wetting of the food to bring chemicals into contact with it. The digestive juice in the mouth is saliva, which is secreted by three pairs of glands. These glands can be located by running the tongue around the inside of the lips and mouth. About three pints

of saliva are secreted daily. Saliva acts on the starches changing some of them to sugar, as shown in the experiments of testing for sugar. There is not time enough for the saliva to digest much of the starch during the short time the food stays in the mouth. The work begun here is finished later by another juice in the small intestine.

When food is swallowed, the little gate, or epiglottis, covers the windpipe and prevents food from getting into the lungs. The digestive and breathing tubes cross in the back of the mouth. Swallowing is a definite pushing along of the food by the muscles of the food tube.

What digestion takes place in the stomach? The stomach is a pear-shaped pouch which, when full, is less than a foot long and five inches wide. It is capable of holding about two quarts. There are valves at each end of the stomach to regulate the movement of food. Contrary to the general idea, the stomach is not chiefly a digestive organ, but it is a storehouse which prepares the food for digestion later in the system. Food stays in the stomach ordinarily for two or three hours. During this time it is very slowly turned over and over, constantly becoming more liquid.

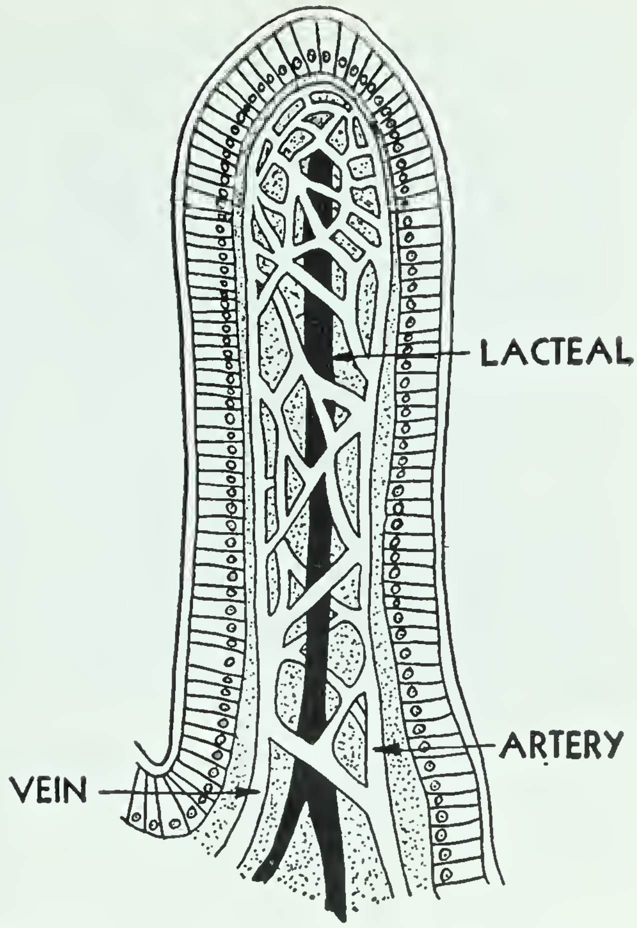
There is a difference in the length of time that various foods remain in the stomach. Fat and protein foods stay in the stomach about three hours on the average, while fruits and vegetables pass through the stomach in about two hours. The amount of time that food remains in the stomach differs with different people, this difference being as much as 30 minutes to an hour in some cases.

Food is acted on by two chemicals in the stomach: hydrochloric acid and the gastric juice. The acid neutralizes the saliva, which is alkaline (like a base). Every normal person has an acid stomach. The gastric juice starts the digestion of the proteins, changing them into simpler substances.

The opening leading from the stomach to the small intestine is kept closed most of the time by means of a strong muscle band. Every little while this opens momentarily, thus allowing some of the food to pass from the stomach into the small intestine.

What digestion takes place in the small intestine? The small intestine is the chief digestive organ of the body. In

it three juices act upon the food: the pancreatic juice, which comes from the pancreas; the intestinal juices, which come from glands in the walls of the intestine; and the bile, which comes from the liver. The bile is stored in the gall bladder.



This projection (greatly magnified) on the inner wall of the small intestine has the function of absorbing food. The lacteal is a lymph tube which carries fluids toward the heart.

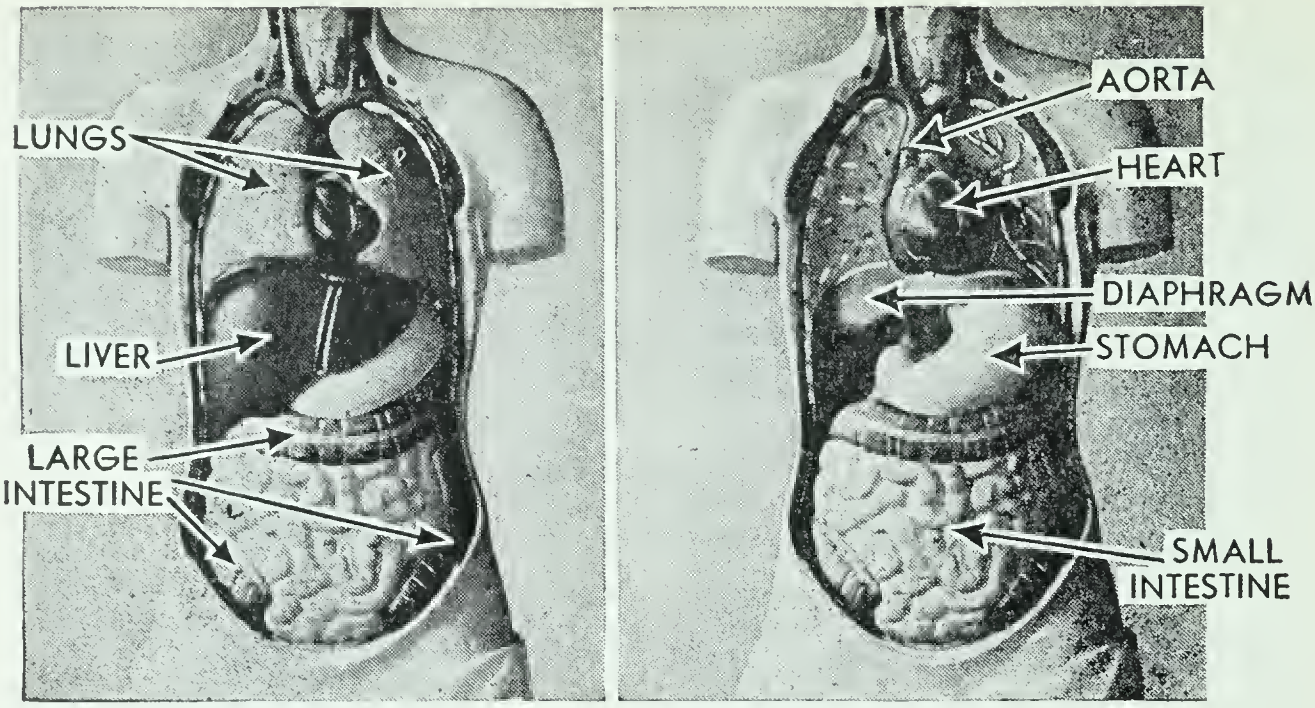
The pancreatic juice is the most important digestive fluid. This juice is secreted or produced by the pancreas, which is located just below the stomach. It pours about a quart of digestive juices daily into the upper end of the small intestine. The pancreatic juice acts upon starches, fats, proteins, and sugars. In the upper third of the small intestine the bile begins its action upon fats. Since fats do not dissolve, the action of bile is to form soap-like compounds which form emulsions in the digestive fluids.

In the lower two-thirds of the small intestine the intestinal juices complete the work of digesting whatever is left undigested.

In the large intestine bacteria and yeasts act upon indigestible waste materials which pass through the small intestine.

Most of the work of digestion is the result of action of chemicals called enzymes [ĕn′zīm] or ferments found in the digestive juices. There are at least 10 different enzymes in the digestive juices, each with its own chemical activity to perform.

How is food absorbed? As the food is digested and passes through the alimentary canal, it is absorbed into the blood stream. From the stomach simple sugars and alcohol may be absorbed. In the upper third of the small intestine some



Does your school own a model like this? The first view shows the organs in place. The second shows part of the lungs removed to expose the heart, and the liver removed to show the stomach.

quickly-digested foods and soluble minerals and vitamins are absorbed. Most of the foods are absorbed in the lower part of the small intestine. The large intestine absorbs only water.

The small intestine has special folds and finger-like projections which dip into the digested food and provide a large surface through which food may be absorbed into the blood. By means of the blood, food is carried to the cells of the body.

What is the function of the large intestine? The large intestine is a storehouse for wastes, and not chiefly a digestive organ. Near the beginning of the large intestine is the vermiform appendix, a little tube which now has no use, but which may cause trouble if irritated or inflamed. The disease caused by this condition is called appendicitis.

How does food move in the alimentary canal? The movement of food is slower than most people realize. Food is passed in small amounts from the stomach to the intestine. In the small intestine it remains for five or more hours, and in the large intestine, 20 hours. Food normally may move even more slowly than this. In a normal person it may take indigestible substances two or more days to pass from the body. It is unwise to attempt to speed up this movement by taking medicine. Movement is caused by the slow and rhyth-

mic (with regular motion) contraction of muscles located in the intestine walls.

Can we aid digestion? Although we have no direct control over digestion, yet we can influence it indirectly. We can eat desirable foods. Food is forced along through the intestines by the action of their muscles. In order that this movement shall proceed easily, it is necessary that there should be in the food some indigestible materials. Therefore, we should eat some such bulky foods as fruits, vegetables, and whole-wheat bread. We can also control the time of our eating by having regular hours for eating. Food should be thoroughly chewed. When it is broken into fine particles, a better opportunity is given for the digestive juices to act. Furthermore, we enjoy food better if it is thoroughly chewed, and enjoyment of food aids digestion.

DEMONSTRATION. WHAT HAPPENS TO MILK IN THE STOMACH?

What to use: Milk, test tubes, burner, rennet liquid or junket tablet, vinegar or hydrochloric acid.

What to do: Warm gently a little milk in a test tube (do not boil) and add one-quarter teaspoonful of liquid rennet or one-eighth of a junket tablet. Set the mixture aside for a few minutes.

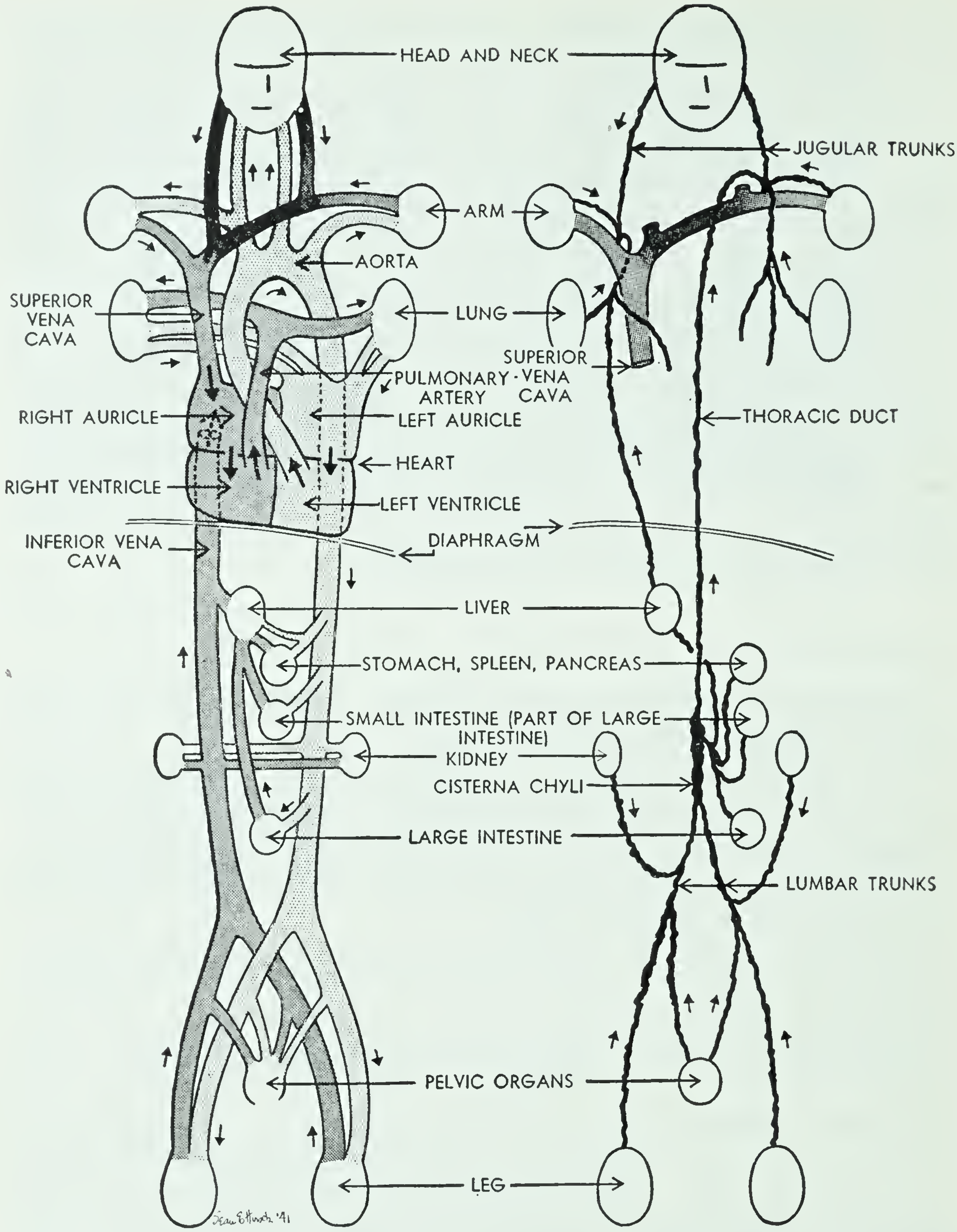
To one-quarter test tube of milk add dilute hydrochloric acid or vinegar and shake the tube.

What was observed: What was the effect of the rennet and the acid on the milk?

What was learned: What changes result from the action of the chemicals found in the digestive juices of the stomach?

Exercise. *Complete the following sentences:* The purpose of digestion is to make food —1—. Starch, when mixed with saliva, is changed to —2—. Gastric juice is secreted in the —3—. Chewing and wetting food is a physical change necessary for —4—. —5— foods are broken down in the stomach. The gall bladder stores —6—. The most important part of the digestive system is the —7—. When —8— are digested, they become soaplike. Fats and proteins are made soluble in the —9—. —10— is the digestive juice secreted in the mouth. Bile aids in the digestion of —11—. The most important digestive juice is that secreted by the —12—.

Science activity. Make a model tooth of soap, showing in cross section how it is constructed.



The diagram of the circulatory system (*left*) shows the four chambers of the heart and most of the important blood vessels. The blood vessels carrying oxygen are shown in a lighter tone. The lymphatic system (*right*) collects lymph from the cells and returns it to the superior vena cava, a big vein. The lymphatic system also collects food from the small intestine. The lacteal shown on page 315 empties into a tube leading to the cisterna chyli. Digested fats in particular are absorbed through the lymphatic system.

7. How is energy released in the body?

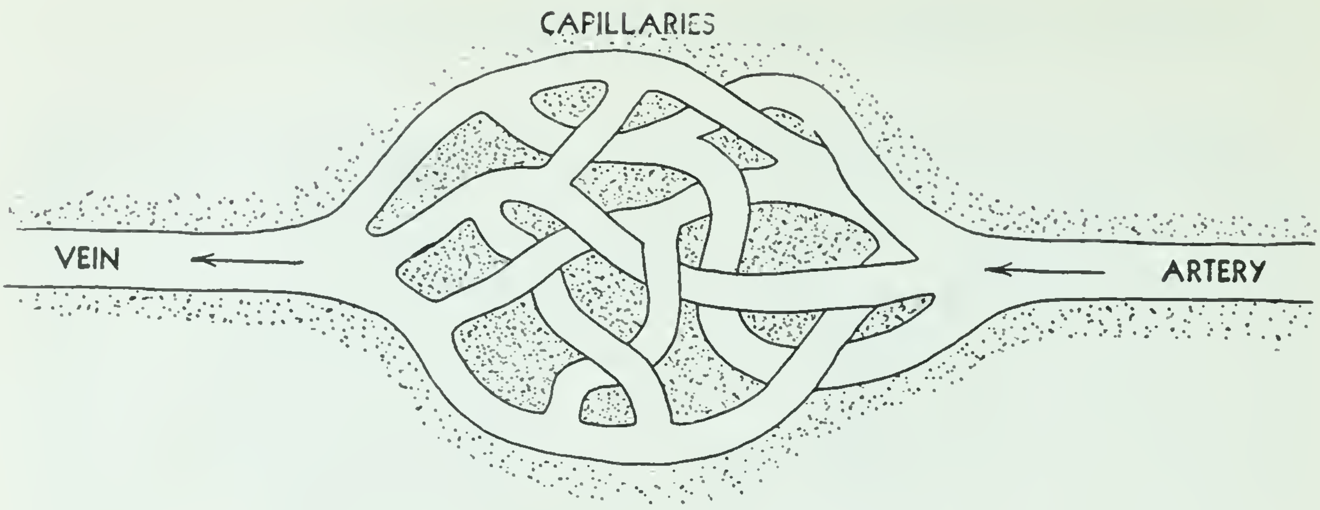
Eating and digestion of food are not an end in themselves. Instead they are essential steps in changing the food into such a form that its energy can be released in the cells of the body. To make this release possible, the dissolved food must be carried by the blood to the cells and brought into contact with oxygen. Release of energy results in movement of muscles or in chemical changes necessary for the functioning of the body or in production of heat to maintain a constant body temperature.

How does blood circulate? The circulatory system consists of the heart, which is a muscular pump; the arteries, through which blood is carried to the body; the capillaries, which carry blood among the cells; and the veins, through which blood returns to the heart. The liquid which passes to the cells from the blood vessels is called lymph. It is collected and returned to the heart through a series of tubes called the lymphatic system.

The heart has four chambers, two on each side. There are two intake chambers, called auricles, and two outlet chambers, called ventricles. The right side of the heart receives blood from the body and pumps it to the lungs; the left side receives blood from the lungs and pumps it to the body. The strongest muscles of the heart are in the left ventricle.

The blood is prevented from flowing backward through the heart and veins by muscular valves. These valves are flaps which form a V opening at the point and which are attached to the blood-carrying tubes along the sides. When pressure is exerted upon the blood enclosed in any part of the circulatory system, the valve on the side nearest the heart is closed, and the valve on the other side of the point of pressure is opened by the pressure. The valves of the heart are supported by muscular cords of fibers which keep them in place.

The pressure of the heart causes blood to flow to all parts of the body. It flows to the intestines where it absorbs food, to the cells where the energy of the food is released, to places in the body where food is used for growth or for storage, and to the kidneys, liver, and other organs for getting rid of



The capillaries are hairlike tubes which connect the arteries and veins. They wind in and out among the cells.

waste. The blood circulates completely every 2½ minutes.

Blood is a complex fluid, being both a suspension and a solution. The carrying fluid consists of salt and water. The blood includes two kinds of cells: the red corpuscles, which carry oxygen, and the white corpuscles, which are the destroyers of bacteria in the body. The blood fluid carries dissolved food, soluble wastes, carbon dioxide, and chemicals necessary for the regulation of the body. The liquid of the blood washes every part of the body except the bones, teeth, and skin.

Because of the pressure within the circulatory system, the lymph must be forced along by greater pressure in order to return to the heart. This pressure is provided by the movement of muscles. It is this fact that explains the relief produced by exercising and rubbing sore muscles. The lymph tubes empty into a vein near the heart.

The heart beats about 120 times a minute in childhood and about 72 times a minute in adulthood. The heart does in a day 400,000 foot-pounds of work, which is equivalent to lifting 20 tons of coal 10 feet.

How is oxygen used in the body? Just as oxygen is essential for burning of fuel, so it is essential for the oxidation of food in the body. The human body, because of its size and because it requires much energy, has special equipment for providing oxygen. We cannot take in enough oxygen through our skins, as a worm can, or through simple tubes, as can the insects.

The lungs are made up of tiny sacs connected to the windpipe by a series of many-branching tubes. As the branching becomes finer and finer, the surface is increased. The capillaries wind and branch over 2000 square feet of surface, bringing the blood into contact with the air. To bring air into the lungs, two sets of muscles—those of the ribs and those of the diaphragm [dī′ȧ·frăm]—expand the chest cavity. The lungs are of soft tissue, having no muscular power of their own. Normal air pressure causes air to flow into the lungs when the chest cavity is expanded. As the muscles of breathing relax, the chest cavity decreases in size, and air is forced from the lungs.

The rate of breathing depends upon age and upon the rate at which energy is used in the body. Babies breathe about 40 times a minute, and adults about 20 times. We breathe faster when we exercise. Each breath of an adult takes in about a pint of air, although by breathing deeply a man can take in more air than this.

The change which takes place in the blood in the lungs is rather amazing. It enters the lungs loaded with carbon dioxide absorbed from the body cells and with the supply of oxygen in the red corpuscles quite well exhausted. Within a few seconds it gets rid of its carbon dioxide, and the red corpuscles take on a supply of oxygen sufficient to change the color of the blood from a dark, purplish-brown to a brilliant red. The chemical which brings about this change in color is an iron compound, hemoglobin [hē′mō̇·glō′bĭn]. This compound combines with oxygen readily in the lungs, and just as readily gives it up to the cells.

Blood which flows from the lungs to the body is bright red; that which flows from the body cells is dull red. The blood of the body arteries and the pulmonary [pŭl′mō̇·nĕr′ĭ, pertaining to the lungs] veins is bright red in color. Why?

How is energy released in the cells? Every one of the numerous chemical changes in the body takes place in the cells. Most of these changes are complex and but poorly understood. The changes are more than the simple oxidation we observe in burning of fuel and rusting of metals. This oxidation takes place at low temperatures, for the body temperature is normally 98.6 degrees Fahrenheit. No flame or

noticeable release of heat results from many of the chemical changes in the body.

The energy foods—fats and sugars—are ordinarily oxidized immediately as they are released for use. Some sugar is stored in the liver, and some fat is stored in the body beneath the skin and around the muscles and intestines. Stored fat and sugar may be released into the blood stream as needed. The growth and repair foods provide the numerous chemicals required to regulate the body, to digest food, to rebuild protoplasm, and to form the teeth and skeleton. Some of these life processes are the result of chemical changes in certain highly specialized cells; while other processes, particularly the process of growth, are shared by all cells.

Although we may never go to jail, we always live in cells!

Exercise. *Complete the following sentences:* The human heart has —1— chambers. Blood flows from the heart through the —2— and returns through the —3—. The blood plasma, or fluid, among the cells is called —4—. Arteries and veins are connected by —5—. White blood corpuscles combat —6—, while red corpuscles have the function of carrying —7—. A chemical called —8— carries the oxygen in the red cells. All energy in the body is released in the —9—. Energy is released as a result of —10—.

Science activities. 1) Ask your butcher to save you the lungs of a chicken. Put a glass tube into the opening of the lung tubes, and blow on it to show how the sacs expand. Does lung tissue float? Look at it under a microscope, if one is available.

2) Catch a live frog and, if a microscope is available, examine the circulation of the blood in the web between the toes of the frog's hind foot. Keep the frog wrapped in a wet towel, and after the demonstration turn him loose where you found him. Ask the teacher to help you keep the frog quiet.

3) Obtain an animal heart from the butcher. Clean it by soaking it in salt water overnight. Demonstrate to the class the arteries, veins, valves, auricles, and ventricles.

8. How are waste products removed from the body?

It is estimated that the body is perhaps 20 to 25 per cent efficient in its use of energy available in foods taken into the body. It is therefore obvious that much of the food material

taken into the body is never oxidized, but passes from the body in various stages of decomposition. From the foods that are completely oxidized, there are the products of oxidation, carbon dioxide, and water. Many of the food materials which enter the body are either indigestible or fail to be digested completely in passing through the mouth, stomach, and small intestines.

Thus there are three types of waste to be removed from the body: carbon dioxide and related gases formed by oxidation, the solid materials remaining in the large intestine, and the materials carried in solution in the blood from the cells. There are four organs active in removing these wastes: the lungs, the large intestine, the skin. and the kidneys.

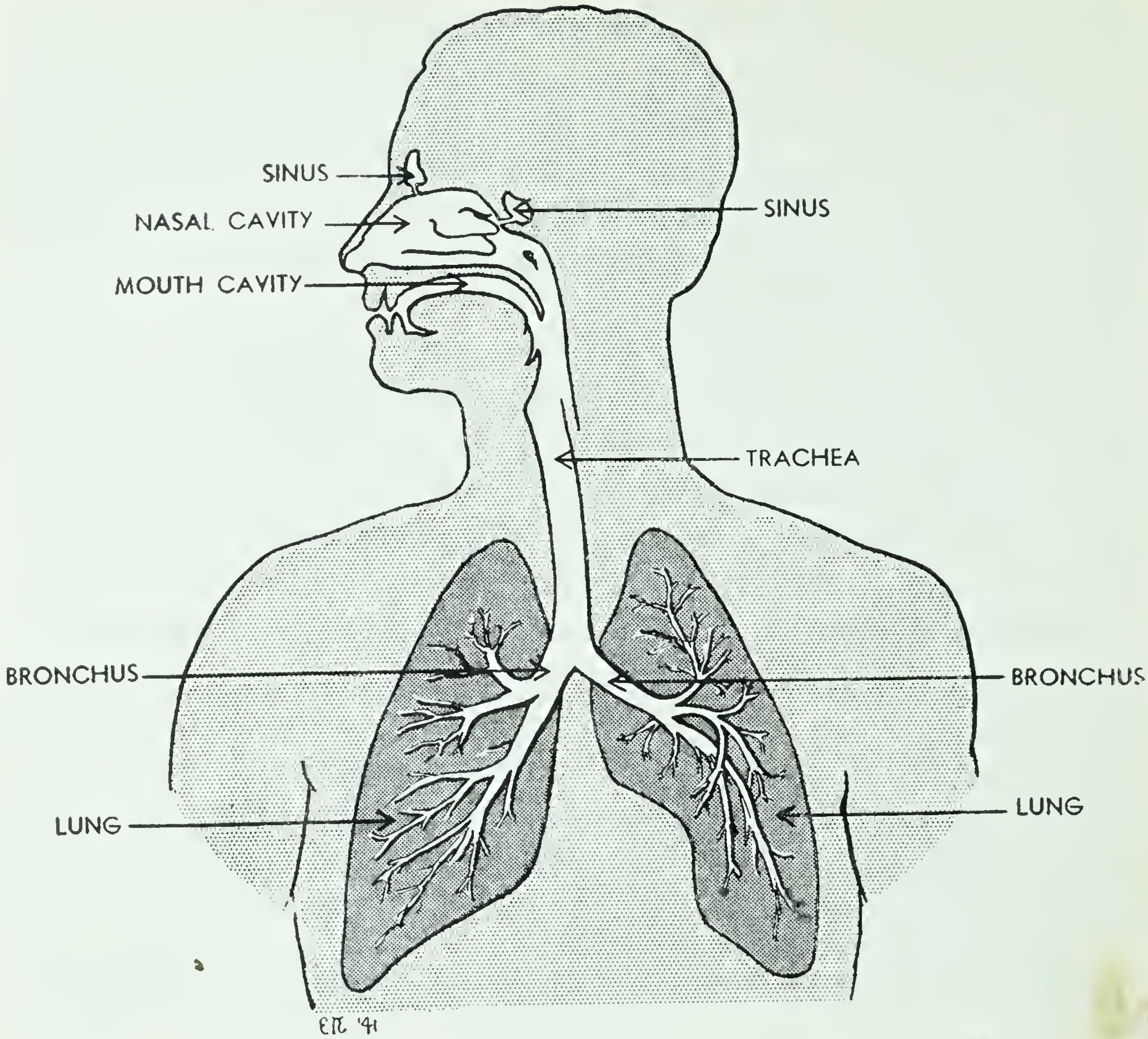
What is the work of the lungs? The gaseous wastes are excreted chiefly through the lungs. The carbon dioxide is carried partly in solution in the blood and partly by the corpuscles. This gas escapes, by processes not too well understood, through the thin membranes of the lung sacs. The composition of air taken into the lungs and that passed out indicates the amount of change produced by oxidation of food.

	OXYGEN (PER CENT)	CARBON DIOXIDE (PER CENT)	NITROGEN, ETC. (PER CENT)
Air breathed in	20.96	.04	79
Air breathed out	17.00	4.00	79

It may be noted that the amount of oxygen in the air is decreased by about 20 per cent, which indicates that the proportion of oxygen absorbed in the process of breathing is rather small. The amount of carbon dioxide breathed out is 100 times the amount breathed into the lungs. The lungs also give off considerable amounts of water vapor.

Control of the processes of breathing is dependent in part upon the amount of carbon dioxide present in the air in the lungs. Pure oxygen is less readily absorbed than is oxygen containing a small proportion of carbon dioxide. Almost pure oxygen is used for breathing by airplane pilots and for treatment of certain illness.

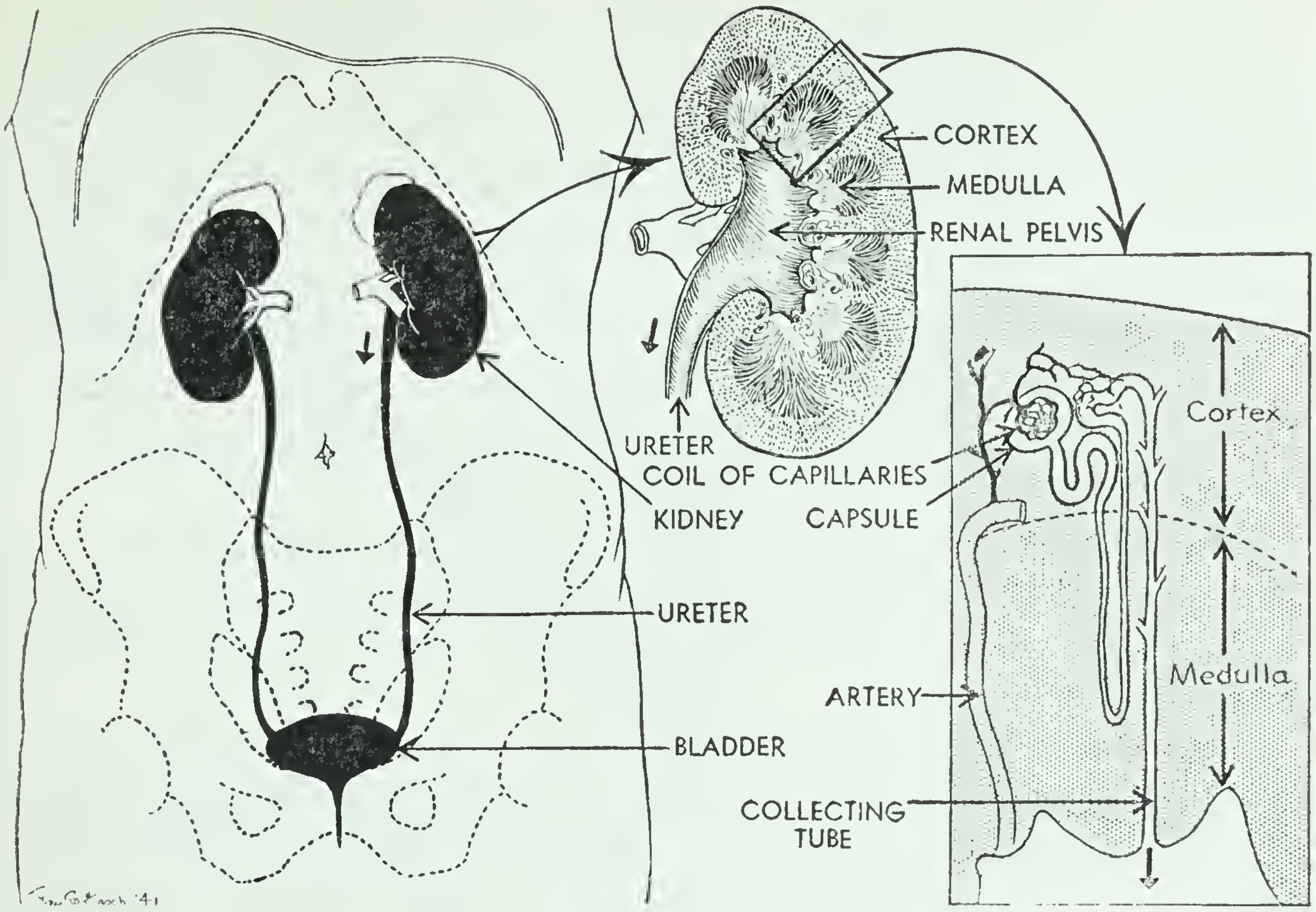
What is the work of the large intestine? The wastes re-



The air is warmed, cleaned, and moistened by the winding nose passages. It is distributed to the lungs by many branching tubes.

sulting from incomplete digestion of food consist of vegetable and meat fibers, skins of corn and beans, wheat bran, seeds, fruit fibers, and cell walls. Mixed into these wastes are enormous numbers of bacteria which produce enzymes which further break down the waste materials. At times these bacteria may make up half the weight of the waste mass in the large intestine. They are generally beneficial to the body in their action. Sometimes, of course, the large intestine contains disease bacteria or worms, which pass from the body into soil water supplies. A standard method of testing water is to count the number of intestinal bacteria found in it. Any purification process that does not remove most of the harmless bacteria may permit dangerous bacteria to escape into the drinking water supply.

The work of decomposition of food wastes in the large



The first drawing to the left shows the location of the kidneys and the bladder; the second shows a cross-section view of the kidney; and the third shows a greatly magnified view of the tubule which collects wastes from the blood.

intestine is accomplished by enzymes produced by the bacteria, and not by any chemicals produced by the body itself.

One of the organs concerned with eliminating wastes from the body is the liver. It is closely netted with blood vessels which bring waste materials from the cells. The liver removes some of these wastes and returns them to the intestine. Most of the work of the liver, however, seems to be to produce bile and to serve as a storehouse of sugar and certain vitamins.

What is the work of the kidneys? There are two kidneys, located beneath the lower ribs of the back. From each kidney a tube called the ureter extends to the bladder, which is located in the lower, front part of the abdomen. The function of the kidneys is to filter out of the blood three products: waste water, the products formed by destruction of protein in the cells, and salts, such as ammonia and table salt. Excretion of wastes is made possible by the action of the cells of the kidney tubules [tū′būlz].

Each kidney is made up of more than a million coiled tubes, the cells of which absorb the water and wastes from blood in the capillaries closely wrapped around each tubule. Every part of each capillary is closely wrapped with kidney cells. In both kidneys it is estimated that there are almost 300 miles of tubules. The total surface of the blood carriers exposed to the action of the kidneys amounts to about 70 square feet.

Each kidney produces a drop of urine in about 30 seconds. The urine flows down the ureter into the bladder, where it is stored until it is expelled from the body.

The amount of water which one drinks determines to a large extent the rate of production of urine. If more water is drunk than is needed by the body, the excess water is immediately excreted.

Does the skin excrete wastes? To a small degree the skin is an excretory organ, for some waste products are carried from the body by perspiration. The materials carried in perspiration are chiefly salts. You can verify this by tasting the skin of your arm.

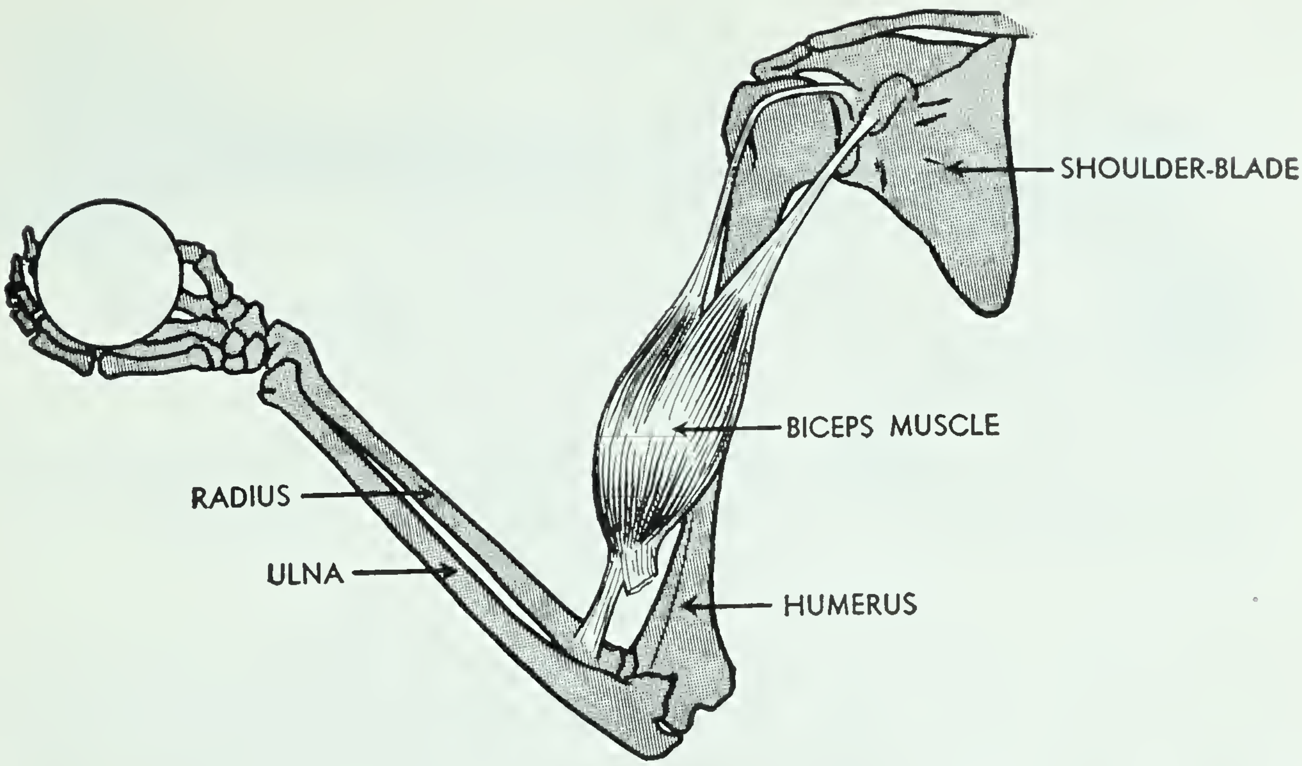
Exercise. *Complete the following sentences:* Products of oxidation are —1— and —2—. The lungs give off body —3— and —4—. Materials given off by the large intestine include —5— parts of food, materials given off by the —6—, and —7—, which act upon the wastes. The kidneys excrete waste —8—, broken-down —9—, and —10—. The kidney consists of many tiny —11— which closely surround the —12— which bring wastes from the cells.

Science activity. Make a sketch of the kidney in your notebook, being careful to label the parts exactly; or make a large drawing to use as a class chart.

9. How is energy used in the body?

The most fundamental difference between being alive and not being alive is the ability of the living body to produce energy to regulate movement, growth, and production of chemicals, and to control the body. Energy changes in the body are production of mechanical, chemical, electrical, and heat energy.

How do the muscles and the skeleton produce motion?



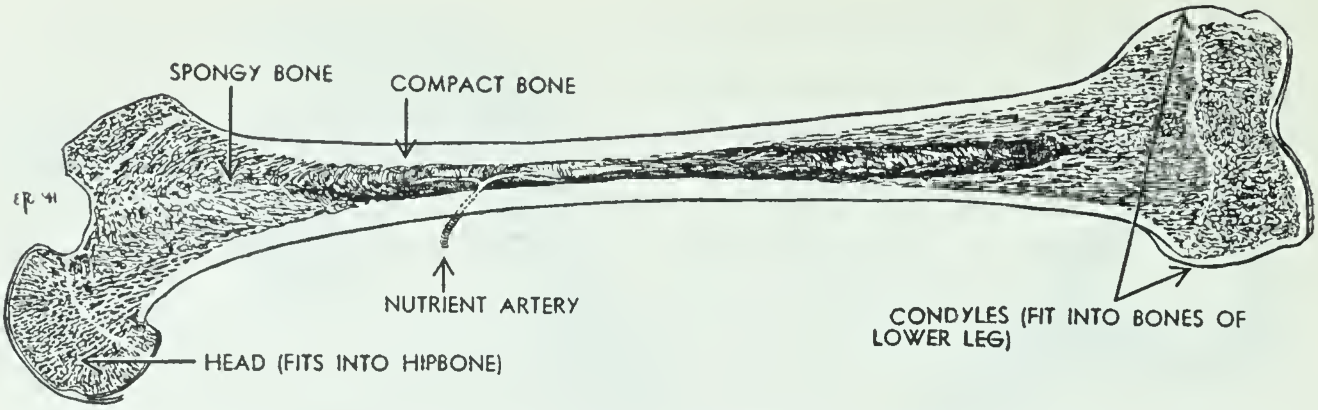
The biceps, the big muscle of the upper arm, is the motor which moves the third-class levers of the forearm. Note how it is attached and how the bones of the arm fit together. Where are the ball-and-socket, the hinge, and the sliding joints?

The muscles which we can control are called the voluntary muscles. These muscles, which are found in the arms, legs, trunk, hands, and feet are the motors of the body. They are made up of long slender cells marked by stripes running crosswise. Voluntary muscles are the ones that make us capable of intelligent action, for we can control them by our mental processes.

The voluntary muscles are generally connected to the skeleton. In fact without the skeleton the muscles would be of little use. The skeleton is a group of simple machines, most of which are third-class levers. The forearm is a typical body machine. The lifting of weights in the hand is done by the big muscle of the front of the arm—the biceps. The elbow is the fulcrum; the hand holding the weight is the resistance.

The muscles are attached to the bones by tendons. The fibrous bands which fasten the bones together are called ligaments.

In addition to the long bones, which are levers, there are other bones which are primarily of use in supporting the body or in protecting tissues so delicate that they would be injured by ordinary activity. The jawbone is the only lever



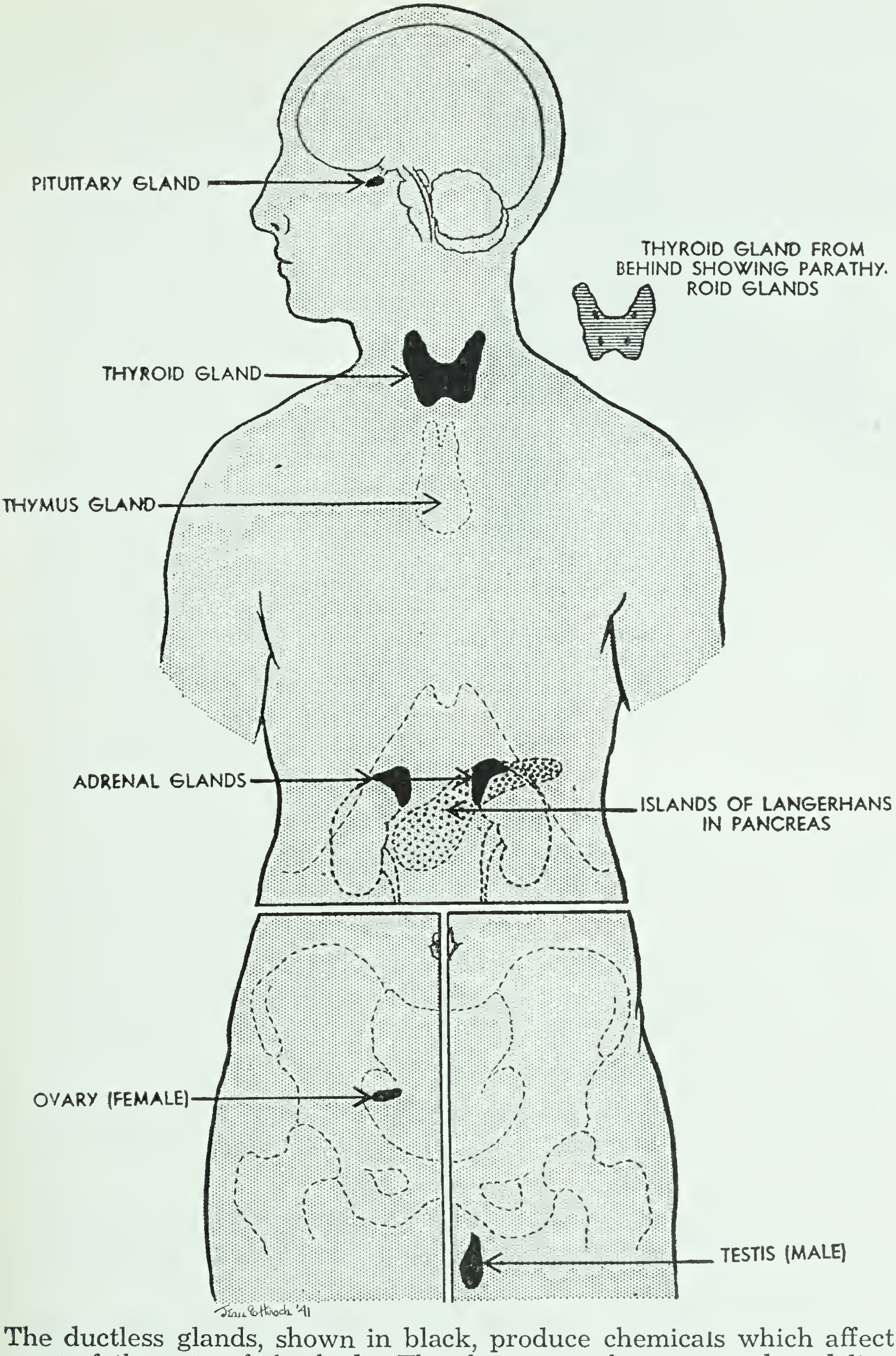
This big bone of the upper leg is strong. Inside the bone is the marrow in which red blood cells are manufactured. Note that a blood vessel enters the bone.

of the skull, the other bones being immovable and placed to protect the brain. The bones of the ankle and wrist are sliding bones, and not directly concerned with producing motion. Rather, they produce a flexible connecting joint between the levers of the arm and hand, and the leg and ankle.

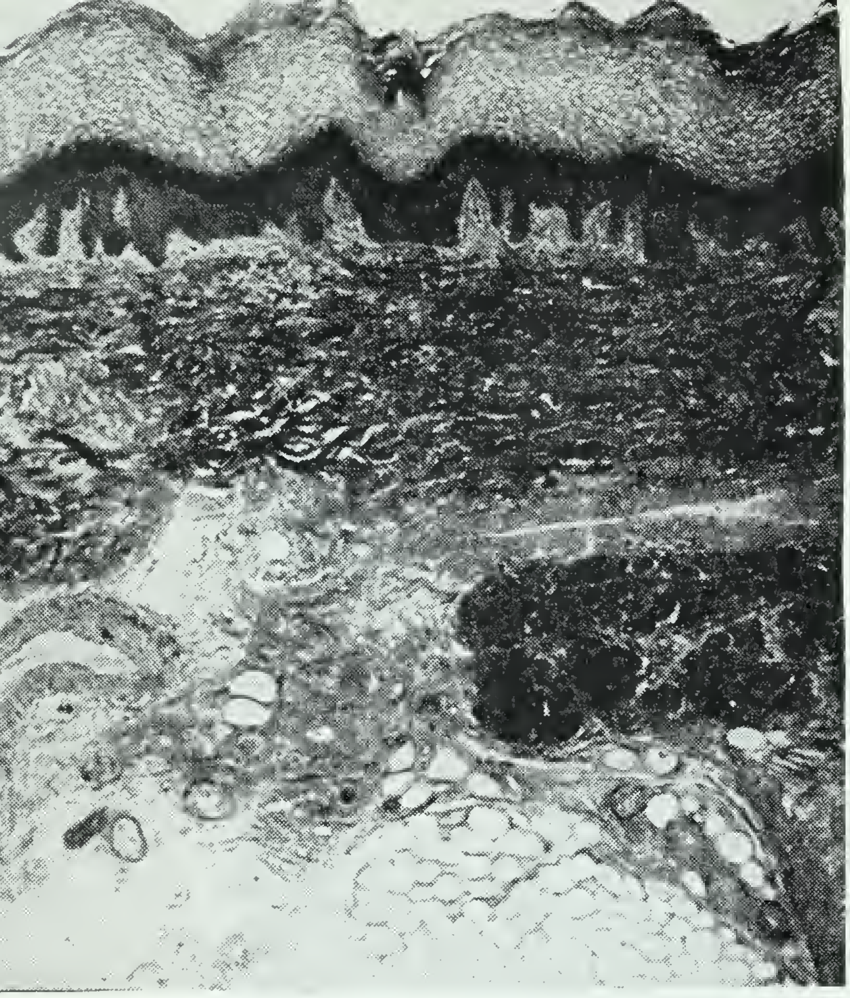
Exercise of the large muscles of the body increases the speed of removal of wastes from the body cells, stimulates appetite, and strengthens the muscles themselves. Circulation is stimulated, and rate of breathing increases. While moderate exercise is desirable, overexercise may be permanently injurious, or even fatal. Exercise is of great assistance in producing normal fatigue and the desire to sleep.

What is the work of the involuntary muscles? The involuntary muscles differ from the voluntary in that we cannot control them and that they have a different form. They are not striped as are the voluntary muscles. These muscles are found in the intestines, heart, and blood vessels. They are regulated by an automatic system of nerves and use considerable amounts of energy. They take care of those activities of the body which are most essential to life—the circulation of blood, the digestion of food, and the supplying of oxygen. While we cannot exercise these muscles directly, we can exercise the voluntary muscles and cause the involuntary muscles to develop as they carry the increased load of work.

Where are chemicals produced in the body? Nobody knows the number of chemicals produced in the body, but it is quite large. The digestive juices—saliva, pancreatic juice, bile, and intestinal juices—are familiar to you. Many parts of



The ductless glands, shown in black, produce chemicals which affect most of the acts of the body. The thymus is shown as a dotted line because it practically disappears when a person becomes an adult. The pancreas itself is not a ductless gland, but the islands of Langerhans are. These regulate use of sugar in the body.



© General Biological Supply House

The human skin consists of the horny epidermis overlying the living dermis. Beneath are blood vessels, muscle tissues, and deposits of fat.

the body are lubricated with a fluid called mucus, which is produced in the mucous glands in the linings of the body.

There are a number of glands which regulate growth, personality, and behavior. These glands are located in various parts of the body. Some empty their chemicals directly into the blood stream, and for that reason are called ductless glands. Among these glands are the thyroid gland, just in front of the windpipe; the adrenal [ăd·rē′năl] glands, situated on top of the kidneys; and the pituitary [pĭ·tū′ĭ·tĕr′ĭ] gland, located deep in the skull. Each of these glands produces one or more powerful chemicals. The reproductive glands in adults produce chemicals which cause many of the characteristic differences between men and women. These glands, of course, also produce the reproductive cells.

One of the interesting results of chemical change in the body is the production of electric currents in the nerve cells. Every time you think, feel, or move, a tiny electric current is produced by a nerve cell.

What controls body temperature? Control of temperature of the body is essential to life. A slight fever upsets the working of the body to a marked degree.

The human being differs markedly from most of the lower animals. Since we are mammals, we are warm-blooded and are able to keep warm as long as we live.

The chief organ for controlling temperature is the skin. Three main methods of getting rid of heat are used. One is the method by which any body cools—giving off heat into the surrounding air by radiation. When you are near a cold win-

dow, you can feel the loss of heat by radiation. The second method operates by control of the circulation of blood in capillaries under the skin. When the body is cool, little blood flows near the skin; but when it is warm, the capillaries enlarge and more blood flows through. The third method is evaporation of perspiration. This is in general the most effective method of getting rid of heat.

Perspiration is produced in the glands of the skin. Evaporation of perspiration takes place all the time, as can be shown by holding a cold glass over any part of the skin. It clouds up rapidly from moisture from the skin. Evaporation cools the body. Slightly more than 500 calories of food energy are required to evaporate a quart of water as perspiration.

On the average, the body gives off about two quarts of water every 24 hours through the sweat glands. That is, you need about 1000 calories of food just to evaporate perspiration. The amount varies, of course, depending upon the temperature of the surrounding air and the activity in which a person is engaged. Vigorous exercise causes free flow of perspiration. The evaporation of the extra perspiration removes the heat freed in the muscles when they become more active. In this case, the heat is waste heat, and must be removed in order to keep body temperature normal. A nice balance is maintained between the heat produced in the body and the amount of heat lost.

The control of temperature by sweat glands is especially important in hot weather. When the temperature of the air surrounding the body gets higher than that of the body, then there is no loss of heat from the body by radiation. In fact heat is radiated to the body from the air. The body, in such cases, depends entirely upon evaporation of perspiration to keep it cool.

The folly of eating ice cream and taking sweet drinks to keep cool is apparent. While a few calories are needed to warm the food in the stomach, the energy taken into the body must be removed through the skin. A large malted milk provides enough energy to evaporate a quart of water. Of course, if you need the energy, malted milk provides it.

There is a very definite mathematical relation between the amount of food eaten, the amount of work done, the amount

of heat given off, and the amount of water that can be evaporated. You cannot beat the game by eating energy foods without having them stored as fat or used to do work.

Certain glands in the skin secrete an oil which keeps the skin soft and flexible.

Is there a relation between use of energy and weight? The chemical activities of the body do not use up a great deal of energy. Most of the energy is released either to keep the body warm or for muscular activity. If too much food is eaten for these needs, the body becomes fat. If too little food is eaten for these needs, some of the body tissues are used up to supply the energy. If the body is underweight, it is possible to gain weight by eating more or by exercising less. *Microscope slide:* Muscle cells.

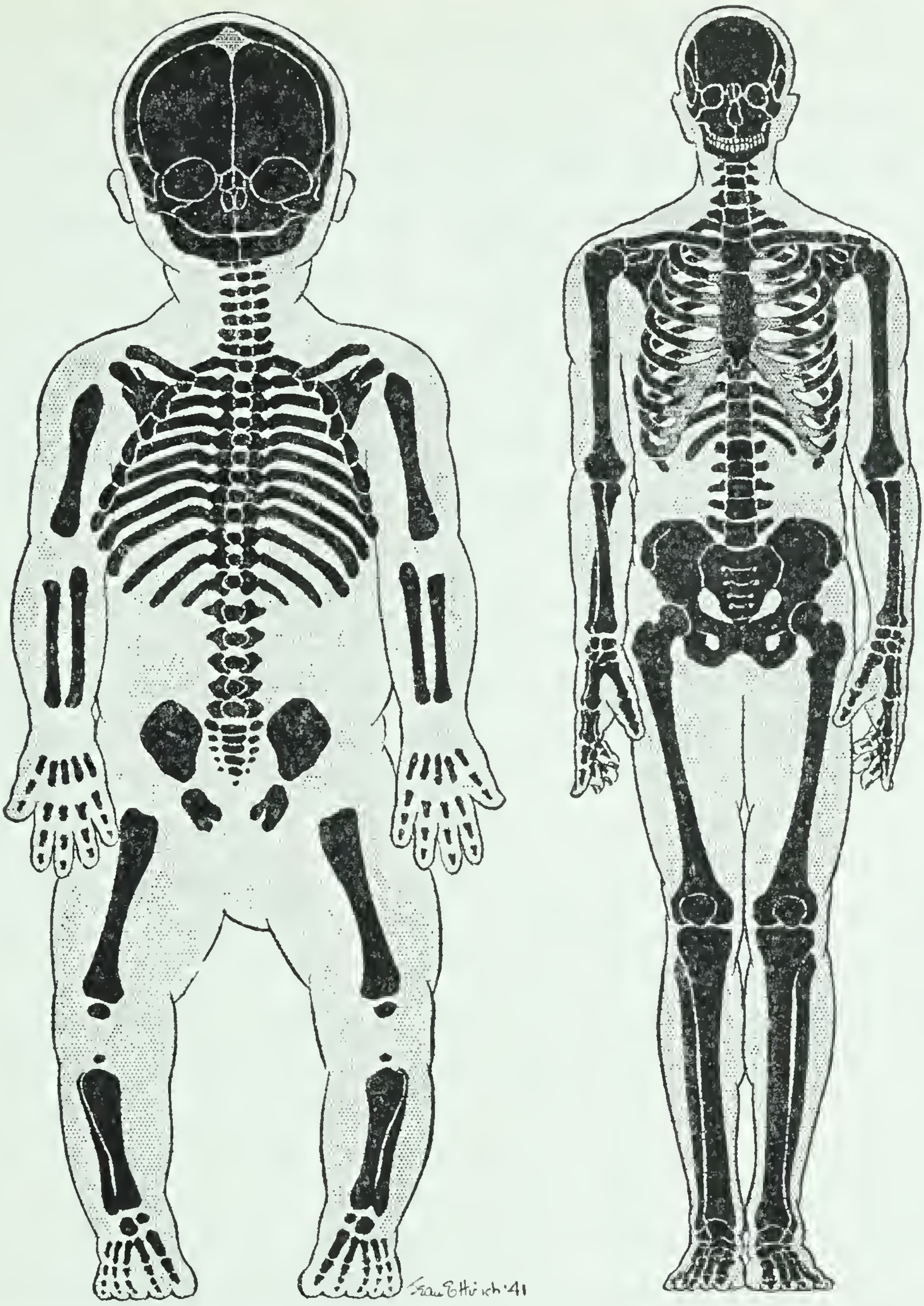
Exercise. *Write a paragraph summarizing this problem, using in it the following words:* voluntary, involuntary, muscle, energy, skeleton, lever, calorie, perspiration, capillaries, radiation, ductless glands.

10. What is the relation of food to growth?

The use of food in the body satisfies three basic needs of life: energy, growth, and repair. The matter of growth and repair are essentially the same process, for repair of tissue results from growth of new cells.

Just what is growth? As you know, every living organism begins life as one cell. Any change in the organism, either in size or in complexity of parts, is growth. It is rather obvious that a gain in weight is the result of growth. The appearance of a beard where there was none before is also a matter of growth.

At the time of birth, the average person is quite well along the road to becoming a full-grown individual, for the average baby weighs about seven pounds. This weight amounts to about 6 per cent of final adult weight for girls and somewhat less than 5 per cent of adult weight of boys. All the food that was used by the baby in its development previous to birth was absorbed from the food supply of the mother. There is probably no more important factor in proper growth than a good start insured by an adequate diet for the mother.


From Scammon, Graca, and Noback

When the body of a baby is shown equal in size to that of an adult, it looks rather queer. Its head is large and its legs are short. Its bones contain little mineral and are soft and springy. The black lines represent bone mineral.

The usual processes of growth are measured from birth, but they do not start there.

What are the stages of growth? For the sake of convenience, growth is divided into four stages. During infancy, which lasts about two years, the baby is helpless and unable to walk or care for itself in even the simplest things. This is a period of rapid growth, slowing down somewhat during

the second year. Childhood extends from the age of 2 to the age of 12 to 15 for most boys and girls. In this stage growth is somewhat slower and is concerned with both increase in size and improvement of coordination of the parts of the body.

The period of adolescence is the age during which boys and girls become men and women. It begins at about 13 for the average girl and more than a year later for the average boy, although it may start for some individuals as early as 9 or as late as 16. Just before adolescence, and during the first years of this period, growth is unusually rapid. During adolescence girls develop the appearance and organs of women. The boys become men. Their voices change and a beard appears. The most important factor in growth during this period is the maturing of the reproductive organs.

During the final period of growth, adulthood, changes take place very slowly. There is some increase in the size of the bones of the face and some slight increase in the amount of muscular development. Any marked increase in size during this stage is more likely to be due to adding fat than to adding to bone and organic weight. Physical adulthood begins for girls at about 16 to 18 and for boys at 20 to 22.

During the first 13 years of their lives, the average boy and girl are about the same size. During the fourteenth year, the average girl is larger than the average boy; but during the next year, the boy becomes larger and continues gaining until adulthood, when the average man weighs about 30 pounds more than the average woman. Yet in proportion to their final size, boys are behind girls even at the age of 20. The illustration on page 336 shows the relative completeness of growth in weight. The average girl has half her adult weight before she is 11, but a boy is more than 12 years old before he passes his halfway mark in growth. The average girl at 16 has only 5 pounds increase in weight to attain, while the 16-year-old boy will increase about 25 pounds in weight.

What foods are essential for growth? You know already that you need about 24 calories of energy per pound of weight. But a year-old baby needs almost twice as many—44 to be exact. An adult past the age of 30 needs only 15 to 18 calories per pound, while an old man or woman needs only 11 calories per pound per day. From these figures it may be

seen that the process of growth is one which requires energy and materials for building.

But provision of energy is not enough. The protoplasm of which the body is constructed is a complex chemical. You can remember some of the more important elements in protoplasm by fitting the names of the elements into the following "signboard": *C. Hopkins Cafe.* The C stands for carbon, the H for hydrogen, the Ca for calcium, the Fe for iron. Fill in the other elements between by referring to Unit Three. If you eat at this "Cafe" you will still be short copper, zinc, magnesium, sodium, and some other trace elements.

To enable the body to use its food, it is necessary to have the necessary vitamins which regulate growth and repair.

One nutrition expert estimates that to obtain an adequate diet every child out of the milk, orange juice, cod-liver oil, gruel stage should have *at least* the amounts of food in the following table:

Milk—one quart daily

Fruits and vegetables—at least three servings daily, including one raw green vegetable, two cooked vegetables besides potatoes, and orange or tomato juice. Canned tomatoes may be used.

Proteins—two servings daily of egg, meat, fish, or cheese.

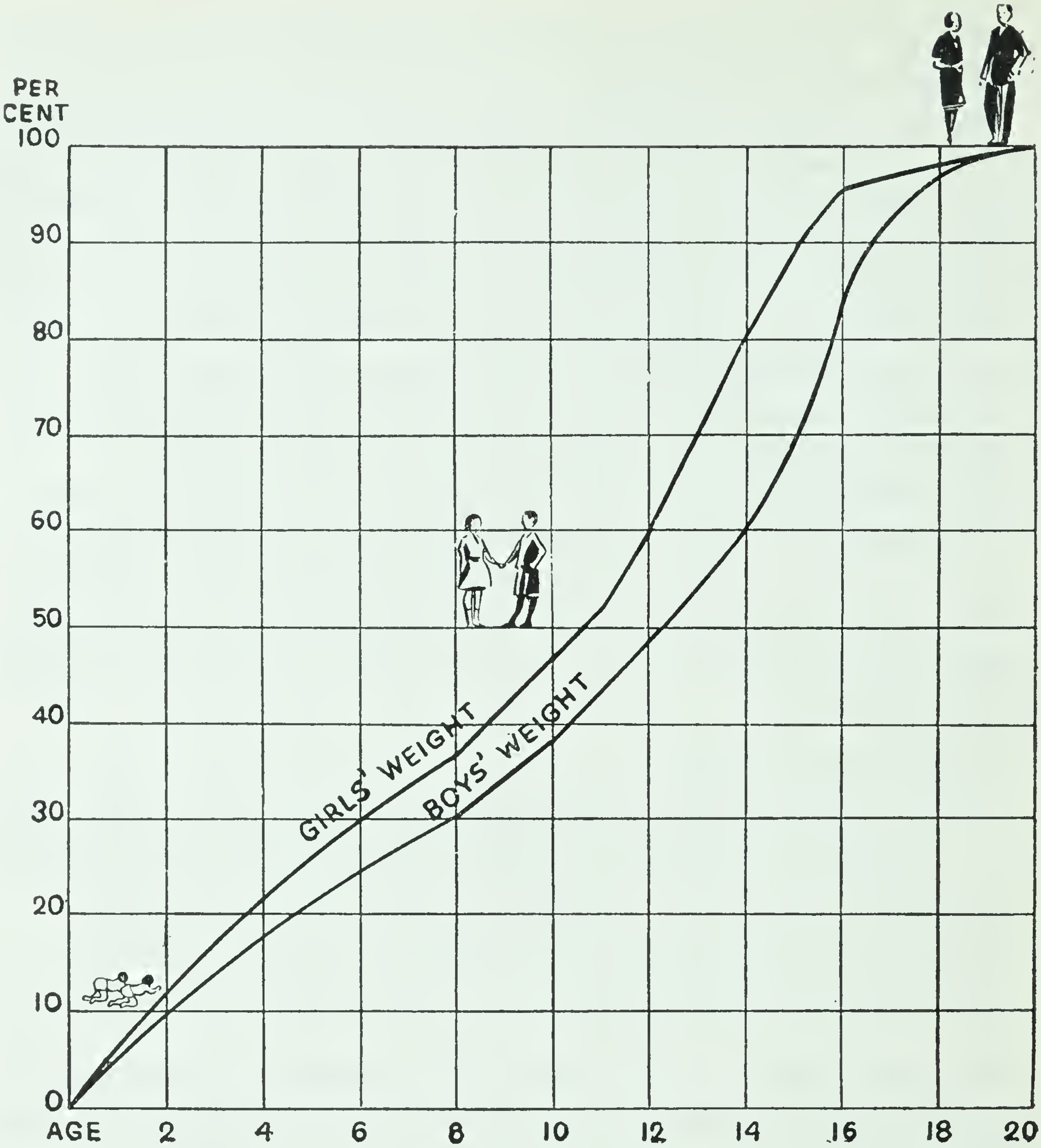
Cereals or bread—whole wheat bread or cereal

Fats—butter at each meal

To this minimum diet should be added potatoes, white bread, fat from meat or vegetables, a little sugar, and other foods of the type needed to supply energy.

What are the body regulators of growth? The controls which cause the changes in rate of growth of various parts of the body operate in a complex manner. Perhaps the most important of these controls or regulators of growth are the ductless glands. These glands, as the name indicates, have no ducts or tubes to lead their chemicals into certain parts of the body but, instead, discharge them directly into the blood stream. They form an interconnected system—that is, one gland may regulate a second, which in turn regulates some process of growth.

The pituitary gland certainly regulates growth of bones, and probably affects muscle tone. The thyroid gland has



This chart shows what per cent of growth is complete at different ages for boys and girls. For example, a girl is 30 per cent grown at six, while a boy is not 30 per cent grown until he is eight.

some influence on proper growth of bones and muscles, as well as upon mental ability. The thymus gland seems to be the one which prevents full maturing of the body until growth is nearly complete, for it almost disappears at the beginning of adolescence. The glands which produce the reproductive cells—the testes and the ovaries—each produce the chemicals required to bring about the bodily differences existing in men and women. The adrenal glands also regulate growth, in coordination with the pituitary and reproductive glands.

There are other glands in the body which also regulate growth to greater or lesser degrees. Much remains to be learned about the controls of growth.

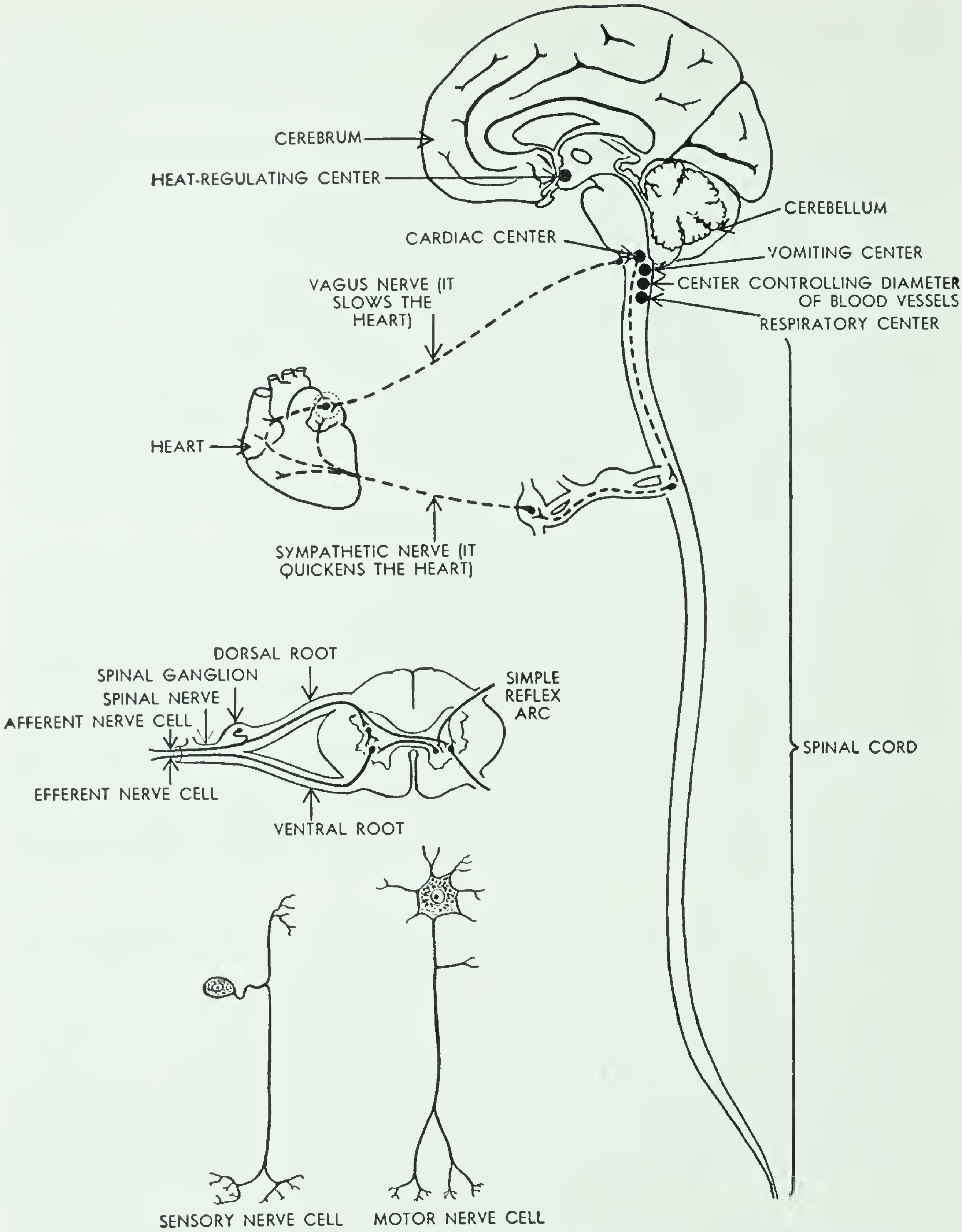
The growth of the body is not uniform, either in the relation of the parts to each other or in relation to rate of change in size. During adolescence these differences in rate of growth may be rather embarrassing, for if the bones grow faster than the muscles can develop to control them, a temporary awkwardness may result. A girl may find to her alarm that her hips seem to be growing rapidly wider, while no other part of her body seems inclined to keep up with them. The feet may become adult while the rest of the body is not. These difficulties are not likely to last long and are unimportant if they do not cause worry.

Because of the sudden spurts in growth that sometimes occur, the amount of food needed may almost double for a few months. The boy or girl is hungry at all times, and the intake of calories may go up from the normal 3000 or 3500 to 5000 or more. One slender, 14-year-old girl ate 6700 calories of food in one day and insisted that she had had only an ordinary amount. She lost her immense appetite after a few weeks, however, and thereafter ate an amount of food normal for her weight.

The best way to check adequacy of diet is to have an occasional medical examination. If weight is normal or slightly above for build, age, and height, and if the child or adolescent has abundant vitality, nutrition is probably normal. The undernourished child is either underweight, or pudgy and inactive. The underweight child is often restless, overactive, and not inclined to sleep well. The pudgy, soft, undernourished child may be getting enough calories but not enough growth-regulating foods, and therefore does not develop muscle or use energy at a normal rate.

Exercise. *Write a summary of this problem, using in it the following words:* birth weight, calories, childhood, adult, adolescence, protoplasm, adequate diet, ductless glands, vitamins.

Science activity. Measure the height of boys and girls in the class. Find the average height. How does this compare with the heights of the fathers and mothers of class members? Make careful observations, and write up a report of your findings.



Locate the organs of the central nervous system. The black circles represent regions which control certain reflex acts. Connected to the spinal cord is shown part of the autonomic nervous system which controls the heart. The reflex arc shows the connection of nerves which control reflexes which are "short circuited" at the spinal cord. The sensory nerve cell carries sensations, while the motor nerve cell controls the response.

11. What organs control our behavior?

To a certain extent every organ of the body controls our behavior in some way. As you already know, structure determines adaptation. We walk upright partly because of the kind of legs and feet we have. Our hands are the most adaptable organs possessed by any animal. We can do such greatly differing operations as threading a needle, operating a typewriter, holding a baseball bat, shooting marbles, shuffling cards, and chinning ourselves because our hands are so flexible, strong, and well coordinated.

But there are other special organs which control, coordinate, and stimulate the activities of all other parts of the body. These consist of the central nervous system, the autonomic [ô′tô·nŏm′ĭk] nervous system, the special sense organs, and the ductless glands.

What is the central nervous system? You know already that the central nervous system consists of the brain, the spinal cord, and the nerves which branch from it. The brain is divided into three parts. The cerebrum [sĕr′ē·brŭm] or forebrain is the largest part. The area of its surface is enlarged by ridges, which give the brain a roughened appearance. The cerebrum is covered on the outside with a layer of gray matter, while the inside is made up of a network of millions of white nerve fibers. The cerebrum is the center of thinking and voluntary action. It also receives the stimuli from the special sense organs.

The cerebellum [sĕr′ē·bĕl′ŭm] is located under the back part of the cerebrum. This part of the brain is concerned with coordination of muscles which operate on the habit level. Walking, maintaining an upright position, and other acts of which we are not aware are controlled by the cerebellum. The medulla is the part of the brain which connects to the spinal cord. It controls breathing, circulation, and some of the reflexes.

The spinal cord connects the brain to the rest of the body, and carries nerve messages both ways. It also includes certain nerve centers, or ganglia, which control reflex acts. The short-circuiting of the reflexes through the spinal cord permits quicker responses than would be possible otherwise.

This is an important matter in escaping danger. We can jerk the hand away very quickly when we are in pain.

What is the autonomic nervous system? The nerves and ganglia which make up the autonomic nervous system are located in the chest cavity and abdomen. This system is not entirely separate from the central nervous system, for the two are connected by nerves. The autonomic nervous system controls many important involuntary actions, such as flow of digestive juices, excretion of wastes, movements of foods along the intestines, secretion of chemicals by the ductless glands, and other kinds of work which are essential to the simplest existence.

What are the special sense organs? You are already familiar with the operation of the eye and ear. The sense of smell, as you know, is dependent upon organs located in the nose. The sense of smell of man is not well developed, and we rarely attempt to train it to any useful purpose. The organs of taste are the taste buds located on the tongue. We have four senses of taste, for we can taste salty, bitter, sweet, or sour materials. All other senses which we call "tastes" are really odors. Apples, onions, and potatoes actually taste very much alike, as you may have discovered if you have ever lost your sense of smell because of a cold.

We have more than one sense of touch. We can feel heat, cold, pressure, and pain. Most of the touch sensations originate in the skin.

A sensation is a nerve current set up by a stimulus acting on one of the sense organs. The nerve current, which is electrical in nature, stimulates other nerves in turn, until the sensation is carried to the spinal cord or brain. Sensations from the special sense organs give us our only means of learning about our surroundings and are our only real source of experience.

What is a response? A response is the behavior brought about by a reaction to a stimulus. It may be a movement of muscles or a flow of chemicals or a nerve current in the brain. We may respond strongly inwardly without showing outward evidence of it. For example, your heart may beat faster at the thought of an exciting game you played, but you do not move otherwise.

What causes our emotions? Have you ever been so upset that your mouth became dry, your knees shook, your breath came faster than usual, and you could not control your actions? If you have, you were affected by chemicals released in your blood by the adrenal gland, which in turn was stimulated by the nerves of the brain and autonomic nervous system. The chemical produced by this gland is carried in the blood stream and causes the release of sugar from the liver. It increases the speed of clotting of blood, as well as the more familiar symptoms of excitement. This emotional condition was highly useful to primitive man in combat or flight, but it is of little use to us today.

This taste bud, magnified one hundred times, is one of the special sense organs. Much of the surrounding tissue is composed of fat.

If we get emotionally upset in a civilized world, we have indigestion, lose friends, and conduct ourselves in unreasonable ways. If we control our emotions, we do not let the autonomic system get our bodies out of control. Controlled emotions make for friendly rivalry in sports and in doing worth-while work. Emotions are the basis for founding homes, for caring for others, and for keeping our self-respect. All these desirable things are dependent upon control of certain glands which operate automatically to cause upsets if once allowed to start action.

Other glands contribute to control of behavior to some extent. Too much thyroid secretion causes irritability and overactivity. Too little causes lack of normal mental development and makes the victim inactive and sluggish.

What are the common types of behavior? Like other animals, we have reflexes, instincts, and intelligence. Reflexes are such simple, unlearned acts as the control of the size of the pupil of the eye, the jerking of the knee, swallowing,

and sneezing. One does not need to learn to act by reflex, for the pattern of behavior is already present in the nervous system as it matures.

Our instincts are more complex than reflexes and are also unlearned. They include such acts as sucking, striking out in anger, and struggling to escape if held against one's will. Instincts are not suitable types of behavior for civilized living, for man cannot get food, make love, and fight as animals do. We must learn to act as our social group acts.

Because we are intelligent, we can learn. Intelligence is the ability to change behavior in such a way that we find solutions to our problems to bring satisfaction to ourselves. Learning is a method of changing behavior.

When we meet a new problem, we may go about learning a solution in one of many ways. One of the most common ways of learning is by trial and error. That is, we keep on trying, and as we make errors, we try to avoid acts which do not bring results. We may solve some simple problems successfully in this way, but we rarely learn effectively by trial and error. Another method of learning is by imitation. That is, we see someone who has a satisfactory response worked out, and try to do the same thing. Much of our effective learning is a combination of trial and error and imitation. It is not natural to eat with a fork. A child first learns to eat with a spoon, missing his mouth as often as he hits it. Finally this complex skill is mastered, and a fork is substituted. Food falls from the fork, for it is harder to handle a fork than a spoon. But by setting an adult standard as a goal, the child finally learns, not only to keep food on the fork till it reaches the mouth, but also to do this work with a fair degree of grace.

The most complex form of learning is reasoning. In this method of solving problems, no physical activity is apparent. In fact if the correct solution is reasoned out, the first act of the muscles accomplishes the correct result. This type of activity is very useful for solving problems, but not so useful for learning such skills as typing.

We do not learn until we feel some emotional need for learning. We may have a personal need for a solution of a problem; we may want to make a good impression on others;

or we may want to beat a rival. We may have a feeling of dissatisfaction with ourselves that is eased only by accomplishing something difficult. Whatever emotional drive we have, this drive makes learning easier and more certain.

Learning seems to depend upon certain nerve pathways existing in the brain and spinal cord. When nerve currents flow through a pathway that gives emotionally satisfying results, that pathway seems easiest to use again. We can learn so well that the response becomes a habit. Learning is not possible until the nervous system and body are mature enough to accomplish the desired result. A two-year-old child cannot throw a ball well, no matter how earnestly he may try.

Exercise. *Complete the following sentences:* The —1— is the largest part of the brain and controls —2— acts. The —3— is the part of the brain which controls breathing. The —4— connects the brain with the rest of the body. Sensations are responses to —5— and are carried by —6— cells. Blinking of the eye is a —7— act. —8— behavior is complex and unlearned. A strong urge to action caused by chemicals produced in the —9— is called an —10—. —11— behavior makes finding solutions to new problems possible, and is the basis of —12—.

Science activities. 1) Learn how to teach a dog or other animal some trick. Bring the animal to school for a demonstration, and explain your methods.

2) When you study this problem, do you start by hunting for answers to the exercise, or do you try to understand the meaning of all the information while gaining minor facts incidentally? Which is the better system?

A Review of the Unit

The human body is a complex organism which is adapted to use the energy of foods to carry on the various life processes. The chief systems of the body are the skeleton, the muscles, the digestive system, the excretory system, the circulatory systems. Each of these parts of the body uses energy in performing its functions.

Food provides the energy. Proteins provide food for growth and repair, and carbohydrates and fats provide a source of energy. Vitamins and minerals regulate body functioning, growth, and repair. Food is oxidized in the cells to which it is carried by the blood. Food wastes are removed through the kidneys, lungs,

intestines, and skin. A balanced diet is necessary for health, and a correct intake of calories is essential for maintaining correct weight.

Body temperature is regulated by the blood vessels and the skin. Most cooling results from evaporation of perspiration.

Our behavior is dependent upon operation of the nervous system and the glands. We inherit some types of behavior, but learn most of the common acts which make everyday living possible.

An exercise in thinking

Match the principles and related ideas, according to the directions given in the review at the end of Unit I.

List of principles

A. The cells require a variety of foods to build protoplasm needed for growth and repair.

B. Work and production of energy takes place in the cells as the result of oxidation of food.

C. The amount of energy in foods is measured in calories.

D. Digestion makes food soluble and changes it to forms which can be used by the cells.

E. The body is controlled by the nervous system and by chemicals produced in the ductless glands.

F. The skin protects the cells of the body and is the heat regulating organ.

G. Body movement is the result of the action of muscles upon the bones.

H. Foods are chemicals which can be detected by chemical tests.

I. Circulation of blood provides food and oxygen to the cells and removes wastes.

List of related ideas

1. All activities of the body take place in the cells.
2. Sugars and starches belong to the class of foods called carbohydrates.
3. The best food class for fuels is fats.
4. The glands which produce perspiration are located in the skin.
5. In times of emotional upset the blood contains more sugar than is normal.
6. The long bones are third-class levers.

7. We can taste salt, sweet, bitter, and sour substances.
8. Chewing and wetting food is a physical change necessary for digestion.
9. Oxygen is carried by the red corpuscles of the blood.
10. The warmth of the body depends upon the chemical activity of the cells.
11. Evaporation of water absorbs energy from surrounding objects.
12. Starch, when mixed with saliva, is changed to sugar.
13. Every kidney tubule is in direct contact with capillaries.
14. Heat is lost from the body by radiation.
15. Carbon dioxide is produced each time a muscle cell contracts.
16. Gastric juice is secreted in the stomach.
17. The cerebrum controls most voluntary action.
18. When food is burned, the mineral matter remains as a white ash.
19. Beefsteak is rich in the food class protein.
20. Protein foods are broken down in the stomach.
21. Iodine mixed with starch gives a deep blue color.
22. Carbon dioxide is carried in solution in the blood.
23. Food combines with oxygen in the cells.
24. Number of calories in food is measured by burning the food in a can surrounded with water.
25. The most important part of the entire digestive system is the small intestine.
26. The voluntary muscles, marked by crosswise stripes, move the bones.
27. Food is used in nerve cells to produce electric currents.
28. A large calorie is 1000 small calories.
29. The body must have a balanced diet for health.
30. Sensations are carried by nerve cells.
31. Food substances necessary for growth and health, which are found abundantly in milk and green vegetables, are vitamins.
32. Kidneys take wastes directly from the blood.
33. Few bacteria pass into our bodies except through the mouth and nose.
34. Fats and proteins are made soluble in the small intestine.
35. Calcium and phosphorus are needed especially for bone growth.
36. Fehling solution turns brick red when heated with some kinds of sugar.
37. A potato, an apple, a piece of chocolate candy, or a tablespoon of butter each furnish about 100 calories.

Courtesy Seattle Chamber of Commerce

A good horse, a mountain trail, fresh air, and sunshine make life worth while. And, incidentally, the exercise increases the rate of oxidation of food in the cells.

38. Movement is the result of the contraction of muscle cells.

39. Vitamins are essential for normal health and growth.

40. Protein is turned yellow by nitric acid and is turned orange by adding ammonia.

Some things to explain

1. Why must everyone eat some proteins?

2. In what ways is the use of food in the body similar to the use of gasoline in an engine or to the use of coal in a furnace?

3. How may one know when his diet is balanced?

4. How can one determine which are the cheapest foods?

5. What part in the use of foods does each of the following systems serve: digestive, circulatory, respiratory?

6. Compare human behavior with plant behavior.

Some good books to read

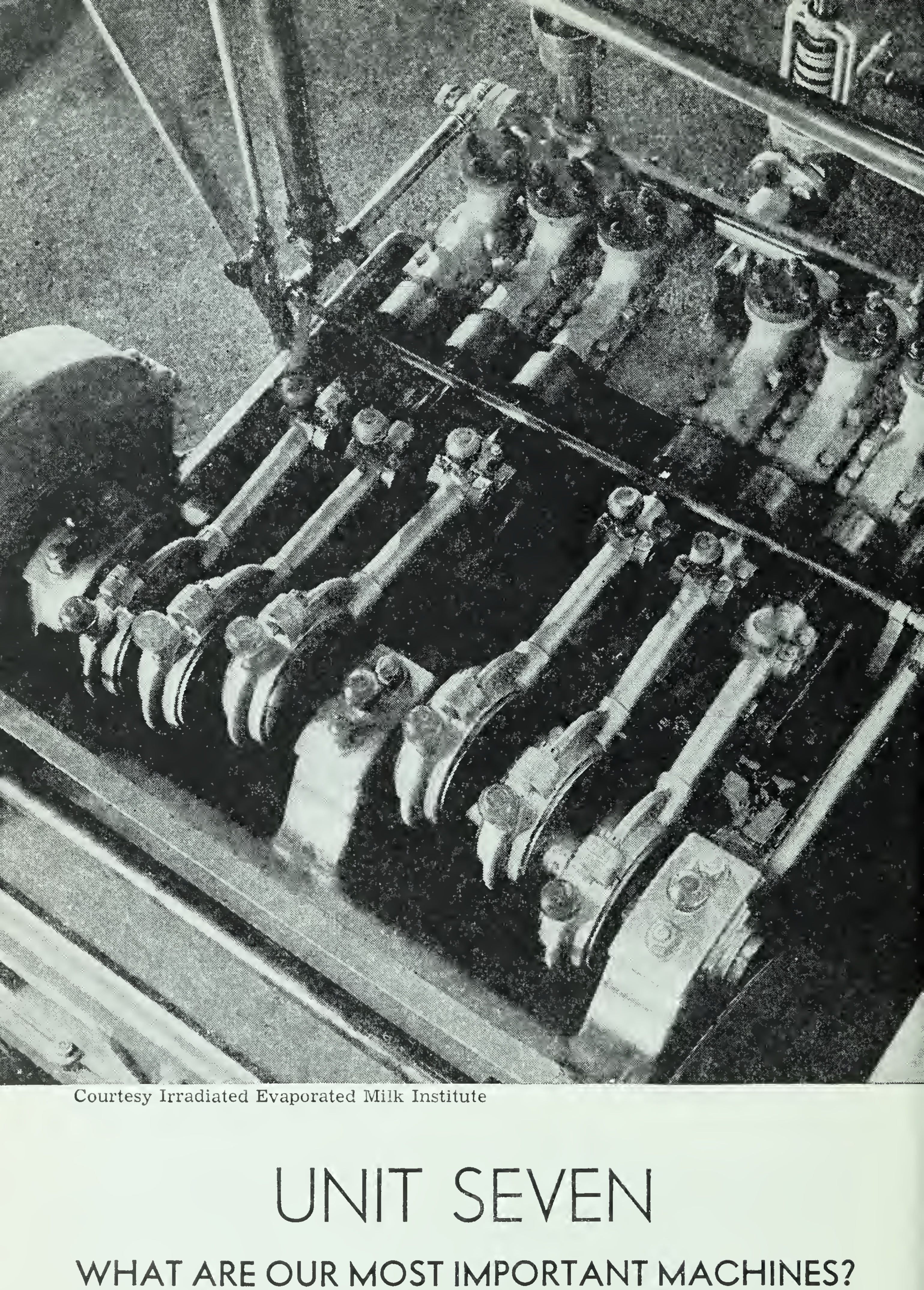
Brekhus, P. J., *Your Teeth*
Chandler, A. C., *The Eater's Digest*
Compton's Pictured Encyclopedia
Crisp, Katharine B., *Be Healthy*
Dana, Margaret, *Behind the Label*
Fishbein, M., *The Human Body and Its Care*
Furnas, C. A. and Sparkle, Velma, *Man, Bread and Destiny*
Kallet, A. and Schlink, F. J., 100,000,000 *Guinea Pigs*
Keliher, A. V., *Life and Growth*
Levine, M. I. and Seligmann, J., *The Wonder of Life*
Plimmer, R. H. A. and Plimmer, V. G. S., *Food, Health, Vitamins*
Rose, M. S., *Feeding the Family*
World Book Encylopedia

Some interesting motion pictures

Food and Growth. Eastman *(16 silent)*
Food Makes a Difference. (2 reels). U. S. Department of Agriculture *(16 silent)*
Digestion. Erpi *(16 sound)*
Heart and Circulation. Erpi *(16 sound)*
Nervous System. Erpi *(16 sound)*
Well Balanced Diet. National Motion Picture *(16 silent)*
New Fashions in Foods. Castle Films, Inc. *(16 silent)*
Story of Milk. Bray *(16 silent)*
Food. Visual Education Society *(16 silent)*

Some related lantern slides

Food. Keystone View Co.



Courtesy Irradiated Evaporated Milk Institute

UNIT SEVEN

WHAT ARE OUR MOST IMPORTANT MACHINES?

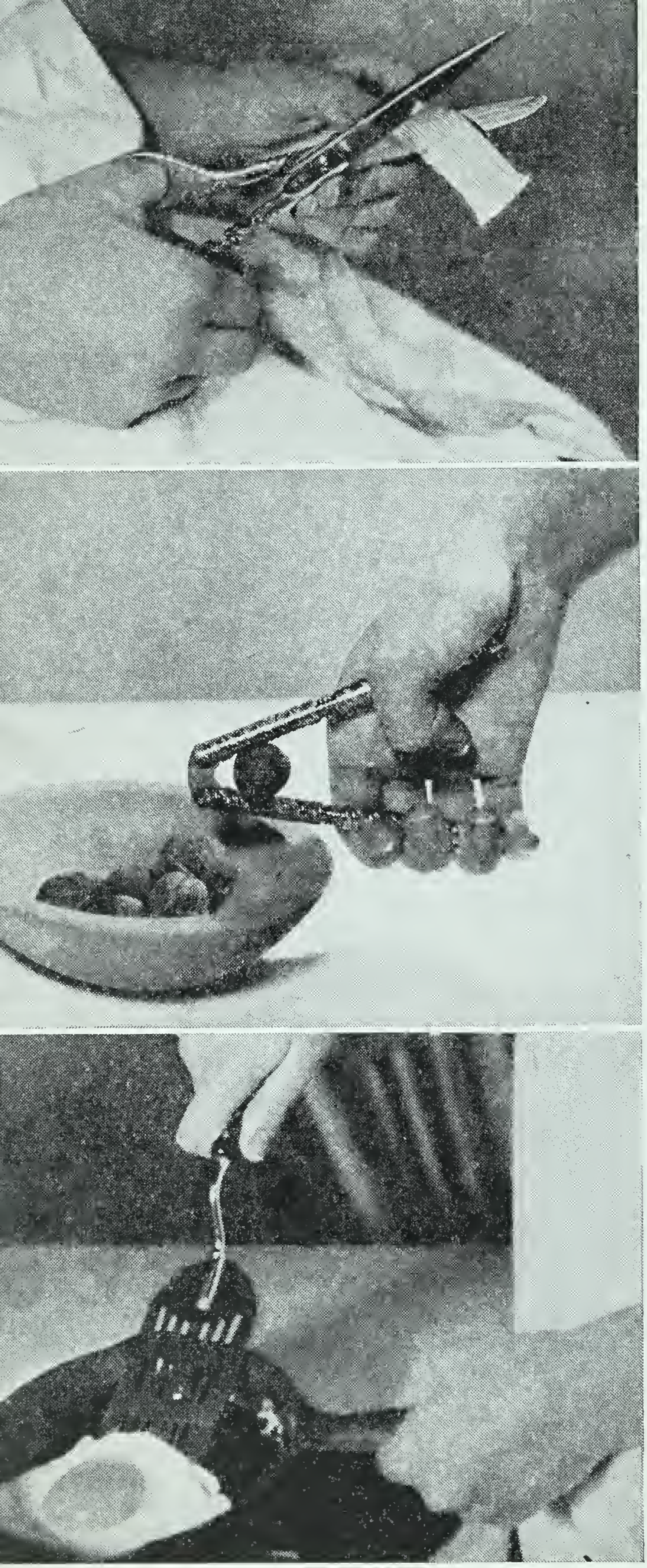
IT IS almost impossible for us to understand today how machines have changed the life of man. We cannot picture the world without machines. Yet only a few hundred years ago the use of machines was confined to crude tools which we would not consider using. For men in the Middle Ages not only did not have automobiles and airplanes, they did not even have sharp axes and good plows. They heated their houses by open fires. They communicated with their neighbors by messenger, sent by horseback or on foot. They did not have sanitary houses, because they had no machines to produce materials needed for plumbing, ventilation, and building.

The invention of machines used in factories brought about a change which you have read about in your history books under the name of the Industrial Revolution. This revolution is perhaps the most important single stage in the change of the way of living through which modern man has passed. It is almost as great a change as was brought about by the use of fire in the life of primitive man or by the domestication of animals and the founding of agriculture in the life of man in prehistoric times.

The Industrial Revolution changed people's way of life in many respects. In former days all the work of making a living was done in the home. The work of spinning, weaving, preparing food, working metal, and other necessary tasks was shared alike by parents and children. But today the parents work in factories or in business, while the children learn how to work in school. Thus the invention of the machine has been responsible for decreasing the importance of the home.

At present, we do not know where the Industrial Revolution will lead, for we are still in it. Machines are now being invented to do tomorrow what yesterday was done by hand labor. We do not know how man will adapt himself to a life in which he does not have to work as hard as he must today. We do not know how to distribute the goods produced by machines. We do not know how to produce things that are good for us and leave alone things which harm us.

Since the Machine Age determines our entire pattern of life, let us try to understand how some of the common machines work.



These common household tools are really levers. The hand in each case supplies the force which the tool or machine applies to good advantage.

1. Why do we use tools?

We know that there are few kinds of work that can be done without proper tools. Tools are so important that it is doubtful that civilization could have developed without their use. The simplest tools —the club, the knife, the axe, and the bow—are known to most primitive peoples. In our own time we know how impossible it is to build houses, repair automobiles, or cultivate the garden without the necessary tools.

Are tools machines? Tools are rather simple examples of a large class of objects called *machines*. A machine may be defined as any device which may be used to apply force to good advantage. To illustrate, suppose you wish to drive a nail. You can hardly do this with your bare hand. Yet with a hammer you can do it easily. The hammer provides a handle to increase the force of your swing and a hard surface to strike against the nail. While you have no more strength when you use a hammer, you do apply force to much better advantage than you could do without it.

The word *force* when used in science has a special mean-

ing. Force is a push or a pull which tends to make something move. Objects do not ordinarily move easily because there are opposing forces which we call *resistance.* The most common resistance to movement is gravity. When an object lies on the ground, it cannot be moved until it is picked up against the pull of the gravity of the earth. Another common resistance is friction. If you have ever tried to open a stuck drawer or to unscrew the cover of a pickle bottle, you know what friction is. A third form of resistance is called *inertia.* Inertia is the tendency of an object at rest to remain at rest until enough energy has been added to start it in motion. You know from experience that if you have a heavy object to move you must start it slowly because of its resistance to motion. Nor is it easy to stop a moving object quickly. Such resistance to change in state of rest or motion is inertia.

Machines apply forces to overcome resistances. If we are successful in overcoming resistance and moving something, then we say we are doing *work.* Unless the object moves, no work is done. Work is defined as a force acting through a distance. Machines apply force to do work.

How do machines permit use of small forces to move large objects? If you wish to move a heavy stone lying on the ground, you do not give up because the stone weighs more than you can lift. You obtain an iron rod, called a crowbar, and dig under the stone until you can slip the end of the bar beneath the stone. Then you put a small stone beneath the crowbar to support it, and throw your weight upon the bar. Unless the stone weighs several times more than you do, it will move. Thus you can use a small force to move the heavy stone. By repeatedly moving the supporting stone and the bar, you can roll the larger stone a considerable distance.

Of course you push the end of the bar through a much greater distance than you move the stone. Thus if you multiply your force four times by use of the crowbar, you move the stone only one-fourth as far as you move the end of the bar on which you push.

Similarly, we use a can opener when we wish to cut metal. While it is possible to cut metal with a knife, it is difficult. The handle of the common can opener multiplies the force,

although we must move it up and down many times to cut around the can.

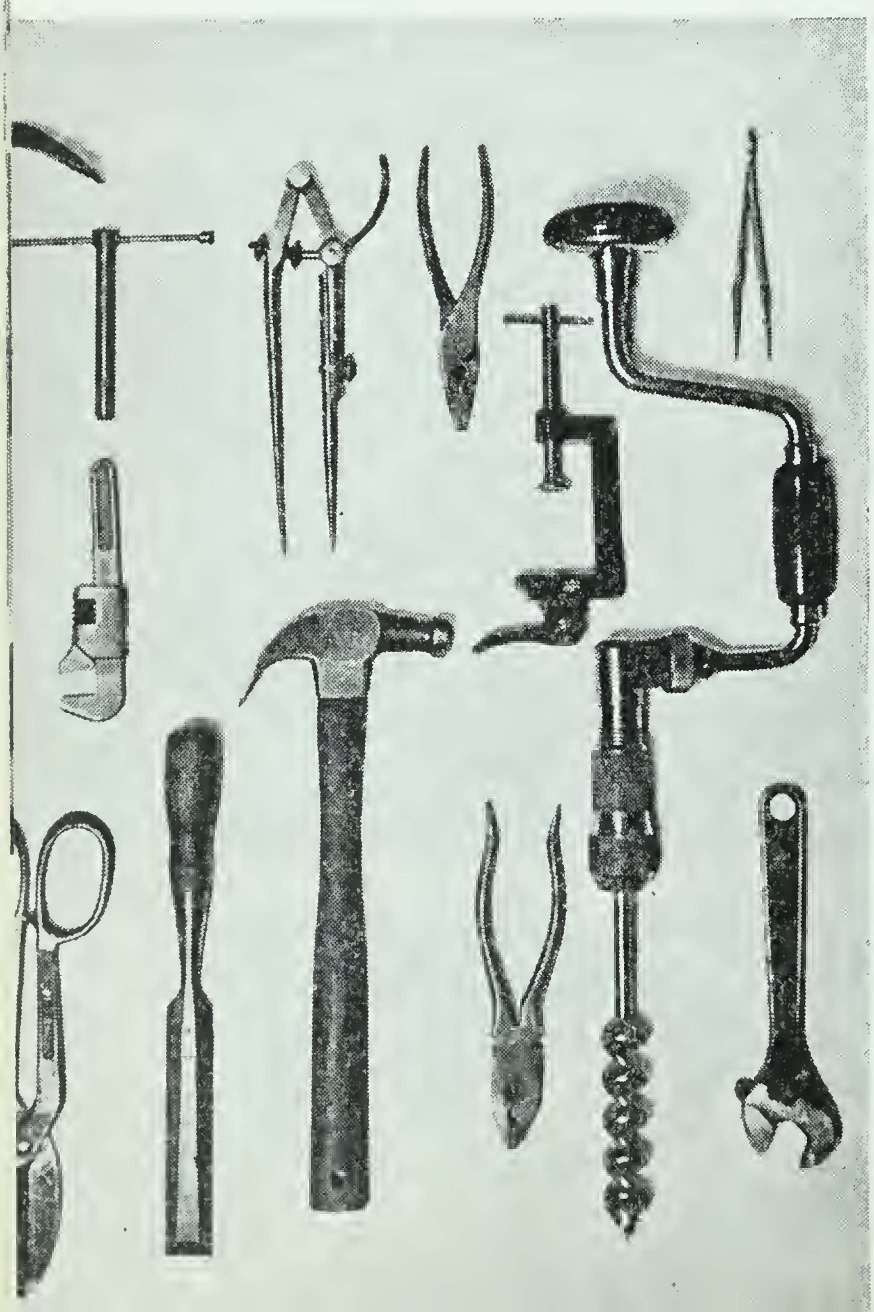
Scientists state the relation between the force and the distance as a law, thus: The moving force times the distance it moves equals the resisting force times the distance it moves. This idea may be stated more briefly:

force $\times$ distance $=$ resistance $\times$ distance *or* fd $=$ rd

Since a force times a distance is work, we may express the same idea by saying that we get as much work out as we put in.

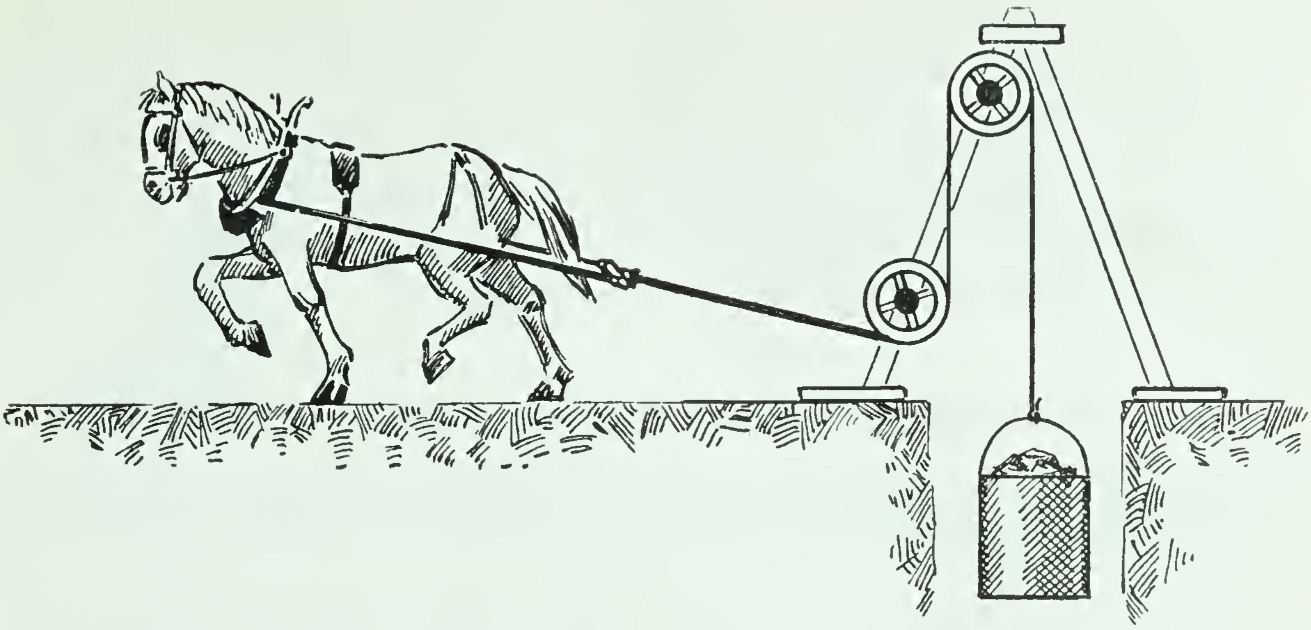
How do machines permit moving small objects through large distances? There are many times when we wish to move some small object through a considerable distance. In this case we must have much more force than we need to move the object. For example, you can move dust along the floor by kneeling down and using a hand brush. Each stroke moves the dust a small distance. By using a broom, you can increase the distance of each stroke because the handle of the broom increases the reach of the arm.

These common tools are also simple machines. For how many tools can you state the most common use? How many simple machines make up all these tools?



Shovels, pitchforks, and rakes similarly increase the distance we can move comparatively small resistances or loads with relatively large forces.

The fishpole is another machine which increases the distance through which we apply the force. When we catch a fish, we wish to remove it from the water quickly before it can escape. The fishpole increases the



The use of pulleys makes it possible for the horse to walk in one direction while exerting force in another. The resistance is the force of gravity. Is there any way you can measure the amount of work the horse is doing?

distance we can move the fish in a short time. If we catch a five-pound fish, we may have to exert a force of 20 to 40 pounds to remove it from the water, however. What we gain in distance we lose in force.

How do machines give advantage of direction or position? There are many times when we do not wish to increase our force, or gain distance, but still we cannot easily reach the object we want to move. For example, it is easier to lower a flag by means of a rope passing over a pulley than to climb the flagpole and carry the flag down.

When we draw water from a country well with a bucket, it is necessary to pull upward on the rope. It is easier to apply the same amount of force pulling downward on a rope passing over a pulley. The famous old oaken bucket was hung from a pulley. This type of machine gives an advantage in the direction through which the force is applied.

Many tools are similarly used to move things not easily reached. Tongs, forceps, and holders are such tools.

What is mechanical advantage? As you know, scientists prefer to use numbers instead of words when it is possible. Mechanical advantage may be defined as the *number* of times a machine multiplies the force put into it. If we are able to use a force of five pounds on the handle of a claw hammer to

pull a nail which has a resistance of 40 pounds, we say the hammer gives a mechanical advantage of eight ($5 \times 8 = 40$).

If we use a force of 14 pounds to lift a two-pound fish on the end of a fishpole, the mechanical advantage of the fishpole is one-seventh ($14 \times 1/7 = 2$). Mechanical advantage may be either a whole number or a fraction.

Demonstration. How Does a Machine Multiply a Force?

What to use: Meter stick, balance support, clamps, weights of 100, 200, 500, and 1000 grams.

What to do: Support the meter stick at the center, causing it to balance. At the 45 cm mark, hang the 1000-gram weight. Consider this weight the resistance. Hang each of the other weights on the opposite end of the balance in turn, in such a position that each weight balances the 1000-gram weight. Measure the distance from the center of the balance to each weight.

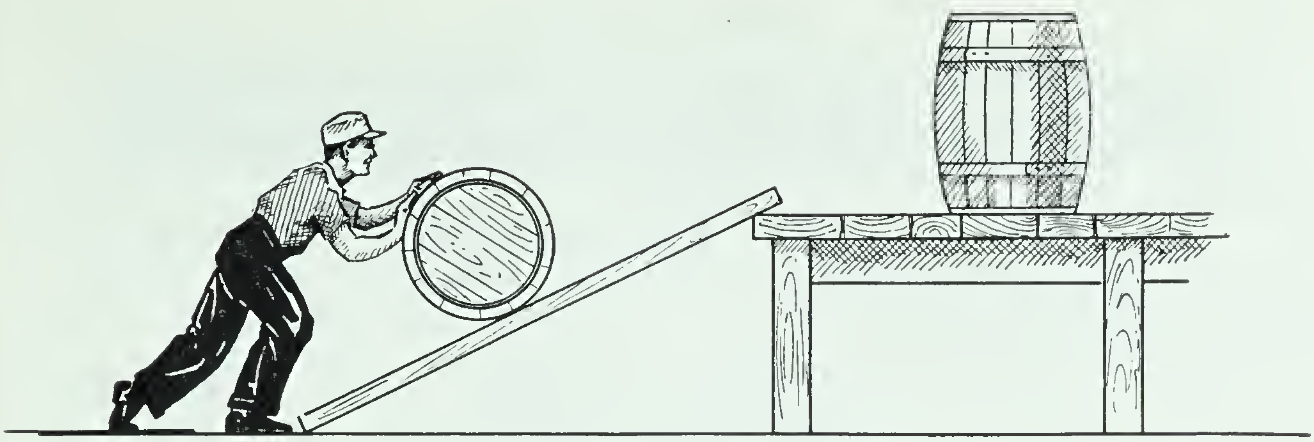
What was observed: Make a list of the distances and the weights. Multiply each of the four weights by the distance it hung from the center. Compare the results.

What was learned: Is there any comparison between the force and the distance and the resistance and the distance on the balance? What is the comparison, if it exists?

Exercise. *Complete the following sentences:* A —1— is a device for applying —2— advantageously. A tool is one kind of —3—. —4— is a push or a pull which tends to overcome a —5— to produce motion. Common resistances to motion are —6—, —7—, and —8—. —9— is a force times a distance. —10— is the number of times a machine multiplies the force put into it. Machines permit use of a small —11— to overcome a large resistance, or they permit use of a large force to move a small object through a greater —12—. A machine also makes it possible to change the —13— in which the force acts.

Science activities. 1) Examine several common tools at home, and list them according to the advantage gained by their use, as explained in this problem. Can you find any tool that is not a machine?

2) Find in a reference book an explanation of the differential pulley. Construct one of a large and a small spool, properly mounted and supported.



One of the simple machines is the inclined plane. Use of the board increases the distance through which the barrel must be rolled but reduces the amount of force needed.

2. Are tools the simplest machines?

It is true that the simplest machines that we use in everyday work are tools. Yet a careful study of the many kinds of tools shows that they can be divided into two large groups: those which are levers and those which are inclined planes. Many of the common tools are combinations of levers and inclined planes.

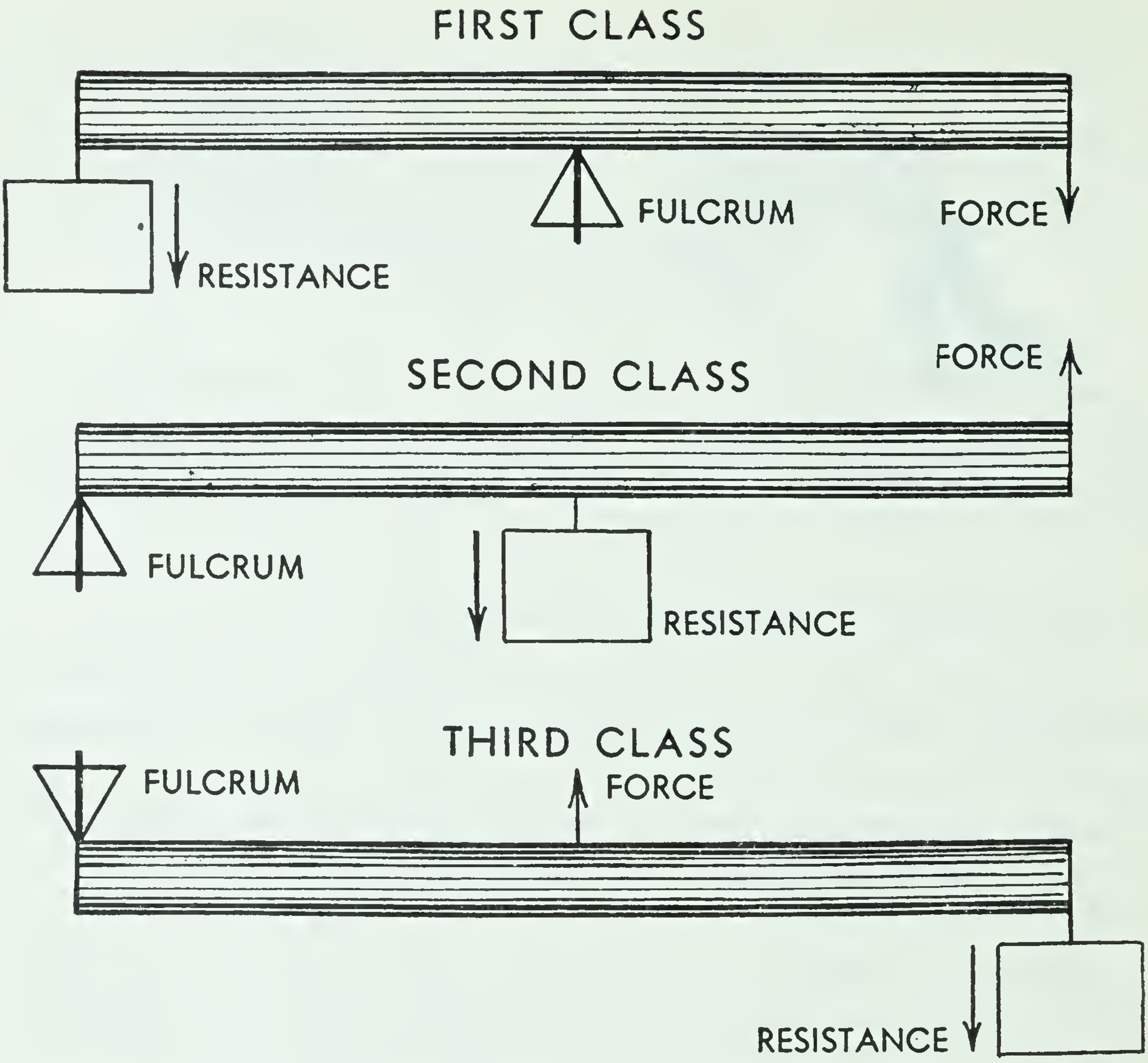
A lever is a rigid bar which turns around a point called the fulcrum. The crowbar, the claw hammer, and the wheelbarrow are common levers. An inclined plane is a sloping surface. A knife blade is an inclined plane—that is, when the blade is laid flat on the table, the top surface slopes upward.

It is perhaps easier to understand these tools if the two groups are further classified until there are six groups of simple machines. The levers may be divided into ordinary levers, pulleys, and wheels and axles. The inclined planes include wedges and screws.

Every common tool may be classified as one or more of the six simple machines. It is perhaps best to study tools in their proper classification, instead of trying to study each tool separately.

What tools are inclined planes? The simplest inclined plane is the skid which is used to roll barrels into a truck. It consists merely of sloping boards. The common doorstop is another inclined plane. All sloping roads are inclined planes. So are sloping ladders and stairs.

The mechanical advantage of an inclined plane is obtained



The three classes of levers differ in the location of the force, the resistance, and the fulcrum. The arrows indicate the direction in which the forces act.

by dividing the length of the incline by its height. That is, a board eight feet long, supported on a platform four feet high, has a mechanical advantage of two. A force of 100 pounds could thus be used to roll a 200-pound barrel up the incline.

What tools are wedges? All the ordinary sharp-edged and pointed tools are wedges. The knife blade, the chisel, the needle, the can-opener blade, scissor blades, and razors are wedges. These tools depend not only upon the amount of slope of their sides but also upon the sharpness of their edges to be effective. A dull knife has spots along the blade which have no slope at all—that is, the plane is not really inclined, but is parallel to the surface of the object cut.

The wedge is used in splitting wood to force the pieces of

wood apart. In this use, the resistance is great, and a small force applied to the hammer must be used many times to split the log. The wedge used in shaving hair encounters very little resistance, and the problem is one of having the blade sharp enough to cut through the hair.

What tools are screws? Many common tools are screws. The fruit-jar lid, the carpenter's bit, the wood screw, some clamps, and some automobile jacks are screws. Monkey wrenches, bolts, and electric-light bulbs have screw threads.

A screw is an inclined plane which is turned around a central rod. The *pitch* of a screw is found by counting the number of threads per inch of length. The more threads, the greater is the mechanical advantage of the screw.

The screw wastes much energy in overcoming friction, for the threads slide against the wood, bolt, or other material in which the screw is turned.

What tools are levers? The levers are the commonest of all machines. They form the handles of most tools, make up the means of carrying force from one part of a machine to another, and serve as balances, teeters, and piano keys.

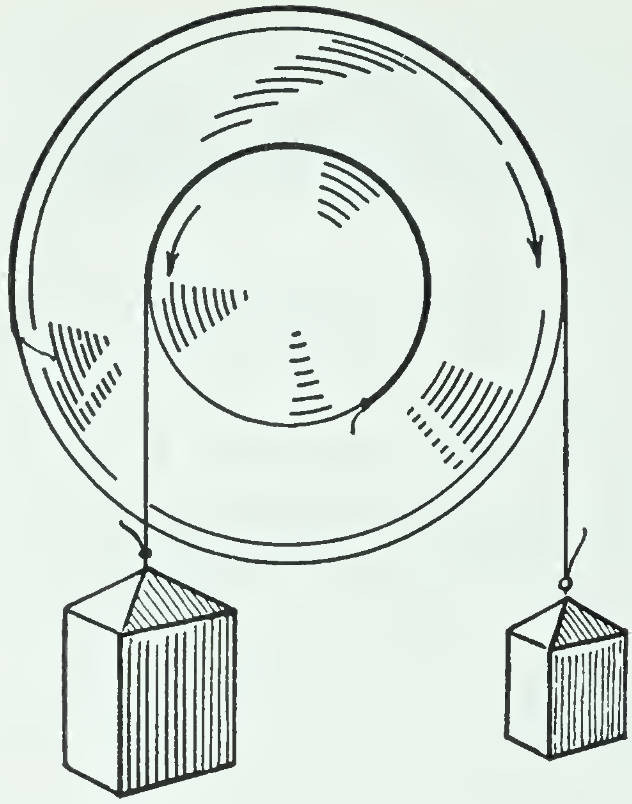
Levers are so common that they are divided into three classes, according to the position of the force, the fulcrum, and the resistance. If the fulcrum is between the force and resistance, the lever belongs to the first class. In a second-class lever the resistance is between the fulcrum and force. In the third-class lever the force is between the fulcrum and resistance.

Some common *first-class levers* are the teeter board, pliers, scissors, the claw hammer, and the pump handle.

Common *second-class levers* are the wheelbarrow, the electric-light key, the common can-opener handle, the nut cracker, the monkey wrench, the carpenter's brace, the handle of the pencil sharpener and egg beater, and the door key.

Third-class levers include the human arm; handles of brooms, shovels, and hoes; laboratory forceps; sugar tongs; and fishpoles.

The mechanical advantage of levers may be found by measuring the length of the arms of the lever. The distance from the force to the fulcrum is called the force arm; the distance from the resistance to the fulcrum is called the re-



The wheel and axle is a lever. Explain the location of the fulcrum, the force, and the resistance.

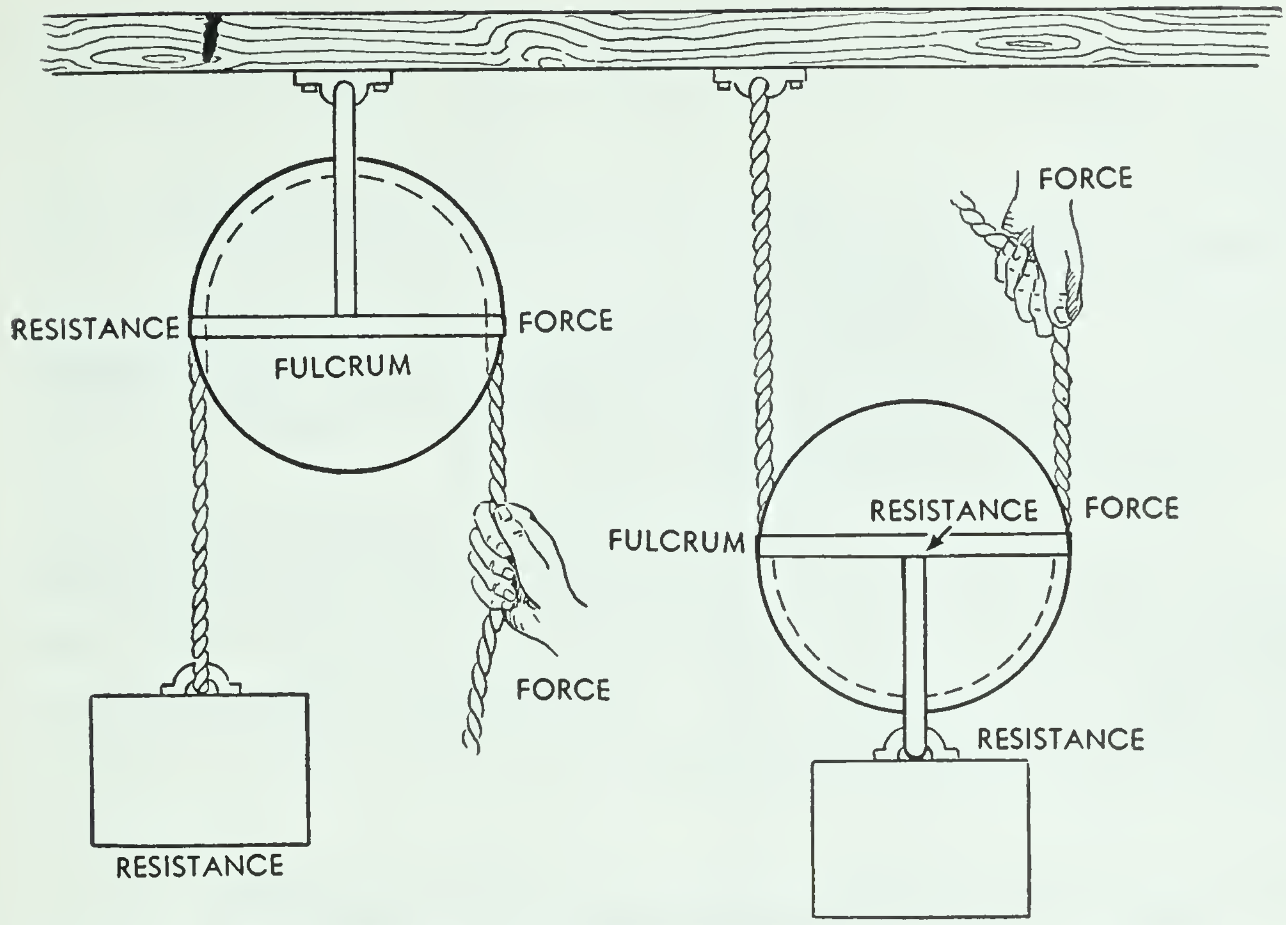
sistance arm. The mechanical advantage of a lever equals the length of the force arm divided by the length of the resistance arm.

The mechanical advantage of a first-class lever may be either more or less than one, but as this lever is generally used, the mechanical advantage is greater than one. The mechanical advantage of a second-class lever is always more than one. The mechanical advantage of a third-class lever is always less than one. To understand these statements, draw diagrams of the levers, and measure distances as explained above.

What tools are wheels and axles? The wheel and axle is really a second-class lever. The steering wheel of an automobile, the dial knobs of the radio, the steam radiator valve handle, and the screw-driver handle are wheels and axles. Some of the less familiar uses of the wheel and axle are in the ship's capstan, which is used to lift the anchor, and in the windlass, which lifts loads from holes by winding a rope around a drum.

What tools are pulleys? You may have trouble thinking of a pulley as a lever, unless you think of the spokes of the wheel as being levers. Pulleys may be arranged in a variety of ways, as shown in the diagram on the next page. One fixed pulley has only one cord supporting the weight and has a mechanical advantage of one. One movable pulley has two cords supporting the weight and has a mechanical advantage of two. When more than one pulley is used, the mechanical advantage may be found by counting the number of cords supporting the weight.

Pulleys are used for a number of purposes. The sash weight is suspended over a pulley. Lifeboats are commonly lowered



The single fixed pulley is a first-class lever. You can observe this fact by considering that two spokes of the pulley wheel make up the lever. Similarly, you may observe that the single movable pulley is a second-class lever.

by use of a combination of pulleys called a block and tackle. The pulley wheels are mounted in the block, and the pulleys and ropes make up the tackle. Pulleys are used on the farm to stretch wires for fences; to lift small loads, such as carcasses of animals which have been killed for meat; and to put hay in the barn.

Another kind of pulley system has a belt passing from one wheel to another. This arrangement is used to carry power from engines to saws, grinders, and other machines.

Demonstration. What Is the Mechanical Advantage of the Inclined Plane?

What to use: Board about 6″ x 4′, small cart, cord, weights, spring balance, ruler.

What to do: Support one end of the board to form an inclined plane. Measure the length and the height of the board from the level of the table. Put the weights in the cart and pull the cart up the incline with the spring balance. Note the reading. Repeat several times to be sure of the reading. Weigh the cart.

What was observed: Divide the length of the incline by its height. Divide the resistance by the force. Are the results the same? Why?

What was learned: What is the mechanical advantage of this particular inclined plane?

Exercise. *Make a table by ruling your paper into six columns. Head each column with the name of a simple machine. Divide the column headed* LEVERS *into three spaces. Into the correct columns write the names of 25 common tools.*

Science activities. 1) Make a collection of tools, toys, and common devices, and make an exhibit of common simple machines. Use care in mounting or displaying your collection, and bring it to school.

2) Make a steelyard balance. You should be able to use it to weigh objects with fair accuracy.

3. How do machines make our work easier?

There are many machines which are used to make our work easier. Some of these machines apply forces other than the force of our muscles. Other machines apply forces to such materials as liquids and gases which we cannot handle with ordinary tools.

The first group of machines makes it possible for us to use the great forces of nature: steam or exploding gasoline, running water, and wind. The second group of machines makes it possible to pump water. compress air, and operate other machines.

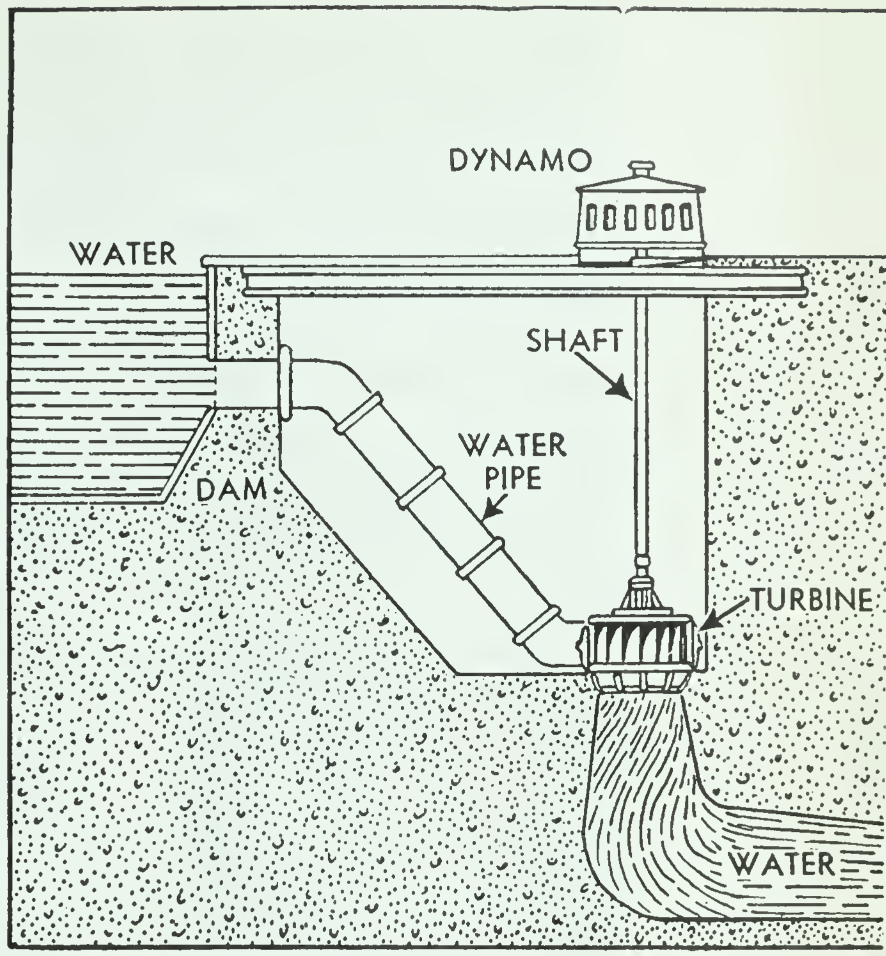
Machines wnich make it possible for us to avoid using our muscles may properly be called labor-saving machines, but not work-saving machines. We can use them to get work done without using our muscles as mere sources of power for machines All these machines provide a moving surface against which the force operates to produce motion.

What machines have moving blades? The windmill, the water wheel, and the turbine are machines which provide a means of applying force to do work.

The windmill is made up of a number of strips of wood or metal, called vanes, against which the wind exerts pressure. The pressure of the wind is greater on the part of the vane

toward the wind than is the pressure of the air on the back part of the vane. Because the vane is set at an angle, it serves as an inclined plane. The wind slides past the vanes, and the vane whirls around the central shaft to which it is attached. The vane also acts as a second-class lever, with the fulcrum at the center of the shaft. The pump rod is the resistance and is operated by a crank on the axle of the wheel.

Windmills are most frequently used for pumping water. A very successful windmill made of propeller blades is used to turn a small dynamo for farm electric plants.



The water-driven turbine turns the kinetic energy of flowing water into mechanical energy which, in turn, is changed to electrical energy by the dynamo.

The paddle wheel used in water-power plants operates upon the same principle as the windmill. Since the water flows against only one side of the wheel, it is possible to set the blades at right angles to the direction of flow of the water. Because water slides off the ends and sides of the blades, much of its force is lost. The water may fall from above and pass over the wheel, as in the case of the overshot wheel; or it may flow underneath, as in the case of the undershot wheel. In the Pelton wheel, water is shot from a nozzle against cup-shaped blades. Because of the greater efficiency of the cups in taking energy from the water, and because of the inertia of the fast-moving water, this wheel delivers more power than do other wheels.

The most effective of all vane-type machines is the turbine. This is a water wheel, or a series of water wheels, encased in a metal cover which directs the full force of the flowing water or steam against the blades. There may be stationary

vanes to turn the water against the revolving blades. Little of the force of the water is lost.

All the revolving-blade machines have the advantage that when they are set in motion their inertia carries them along until the force is used to overcome some resistance other than their own inertia.

Water wheels are used less today than formerly. The turbine is used to turn dynamos in practically all those electric generating plants which depend upon running water for power. At Niagara Falls, at Norris Dam in Tennessee, and at the Grand Coulee Dam in Washington the force of falling water is used to generate electricity.

What are the piston-and-cylinder machines? There are several piston-and-cylinder machines—the gasoline engine, the steam engine, and the gun being in common use. In each case the high pressure required to exert a force upon the moving piston comes from an expanding gas. When a solid or liquid changes to gas, its volume increases tremendously. The compressed gas is hot and expands with great force. For example, the common gun has a barrel, which serves as a cylinder, and a bullet, which acts as a piston. The burning powder forms a gas which exerts pressure on the bullet.

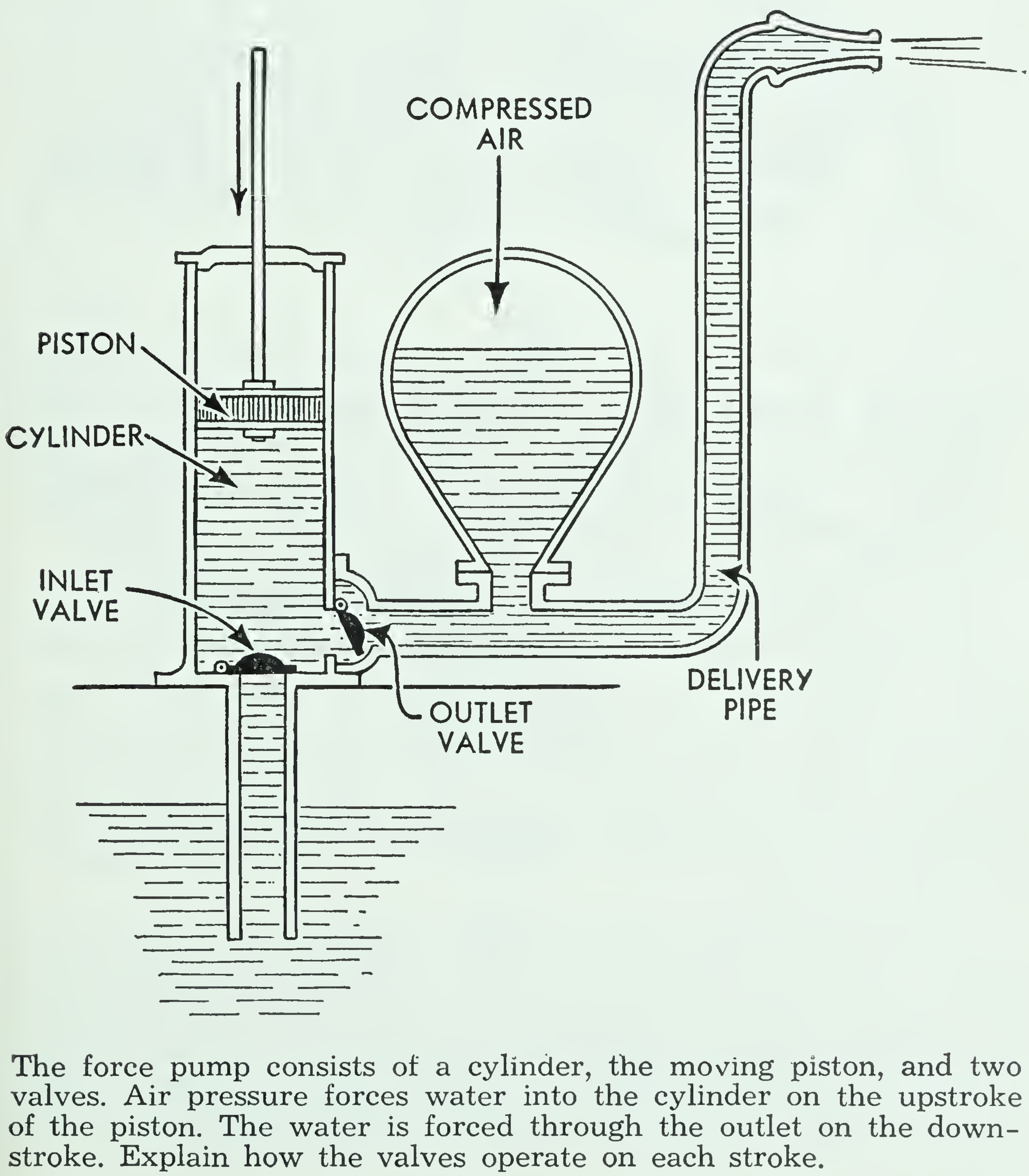
The piston of an engine travels back and forth inside the cylinder. It must stop completely at the end of each stroke. It thus loses the inertia of motion and acquires the inertia of a body at rest. This type of machine is more wasteful of energy than is a turbine.

All machines which use power from gases or liquids depend in their operation upon the principle that when pressures upon opposite sides of an object are unequal, the object tends to move toward the lower pressure.

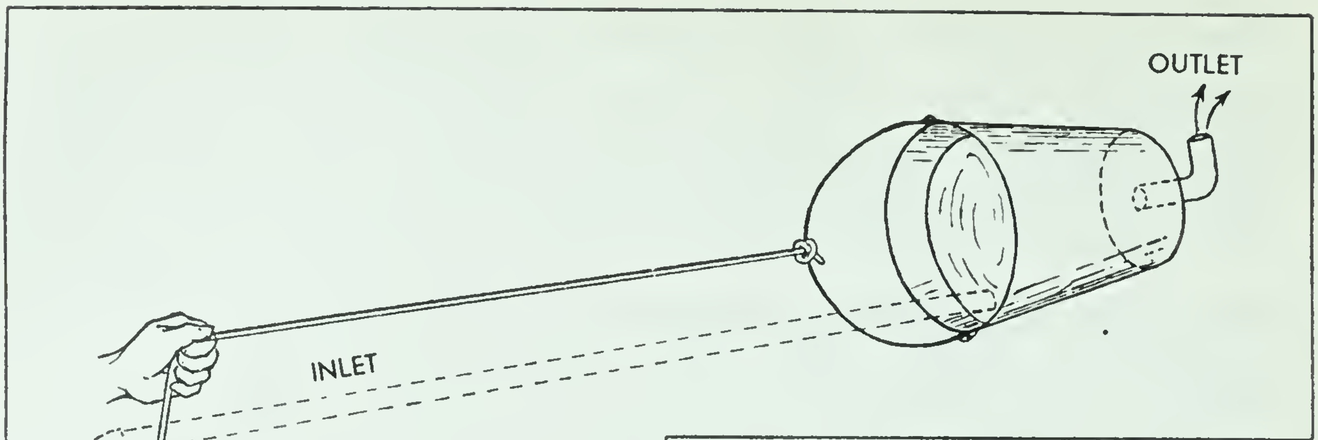
Can machines save work? Work is a force acting through a distance. No matter what force is used, the amount of work done in moving a given resistance a given distance is always the same. Thus it makes no difference whether a tank is filled with water by hand or by use of a pump and gasoline engine. The work done equals the weight of the water multiplied by the height to which it is lifted. How it is lifted makes no difference in the amount of work done. A machine cannot save work, but it can save our muscles.

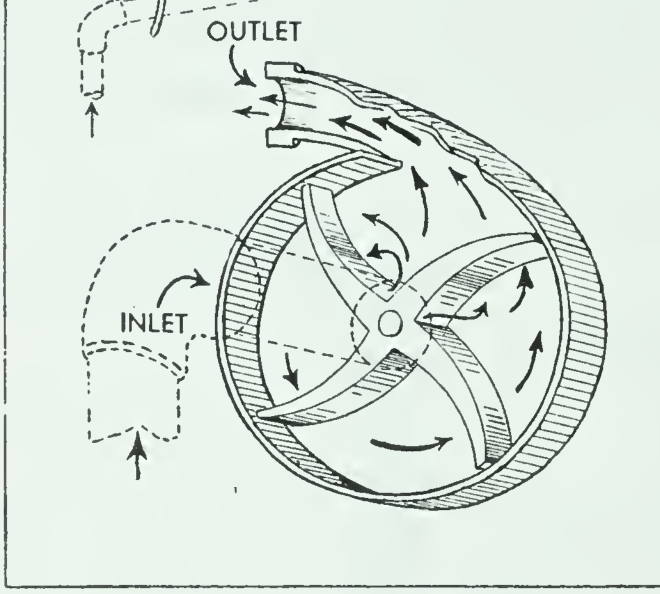
How do machines move liquids? Because of their nature, liquids are difficult to lift. To lift water by hand, it must be held in a dipper or pail. It is tedious to dip water from a well.

In order to lift water by exerting force upon it, it is necessary to enclose the water in a container from which it cannot escape until the force acts upon it. Water can be lifted in this way by pumps. One of the most successful pumps is the ordinary force pump shown in the diagram. The cylinder serves as a container. When the piston moves upward, the pressure inside the cylinder is reduced, and air pressure in



The force pump consists of a cylinder, the moving piston, and two valves. Air pressure forces water into the cylinder on the upstroke of the piston. The water is forced through the outlet on the downstroke. Explain how the valves operate on each stroke.





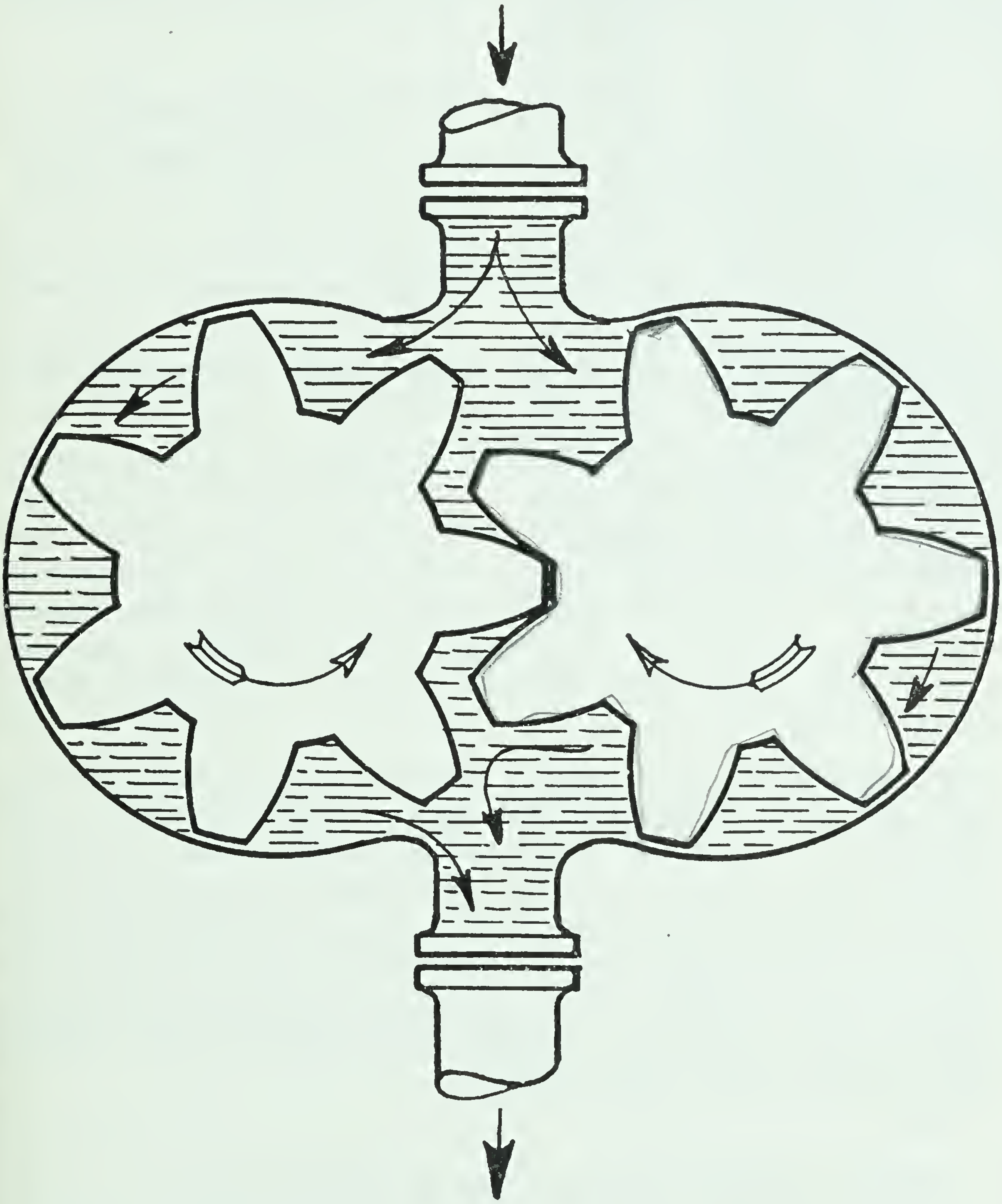
Water flows from the hole in the bottom of the whirling bucket because of centrifugal force. Water whirled inside the casing of the centrifugal pump by the rotating vanes flows from the outlet pipe, also because of centrifugal force. How is this pump similar to a water wheel? How is it different?

the well forces the water into the pump. The valve at the bottom of the cylinder is opened by the flow of the water. When the piston moves down, the water forces the bottom valve to close and opens the outlet valve. This operation is repeated over and over, as long as the piston is moved up and down.

Another pump, which is used frequently for pumping oil and molasses, consists of two sets of gears enclosed in a metal cover. The gears fit so tightly that liquid cannot flow back between them or around their ends, between the gear wheels and the casing. Between the teeth of the gears are many spaces in which liquid is caught. As the wheel turns, the liquid is forced around the outside of the casing and is spilled out in the outlet.

A most interesting pump is the centrifugal [sĕn·trĭf′ů·găl] pump. Centrifugal force is a kind of inertia. A body in motion tends to move in a straight line. When it is held in place by a container or a string, a rotating object tends to fly out of its circular direction. The outward push or pull exerted by the rotating object is called centrifugal force.

If you whirl a pail of water that has a hole in the bottom around your head on a rope, the water shoots out from it with more force than if the pail is not whirled. The centrifugal pump employs this principle—that is, it whirls the water around rapidly until it gains considerable force, and then



Courtesy Gould Pumps, Inc.

When the teeth of the wheels of this rotary pump move apart, they create a partial vacuum. Air pressure forces liquid into the spaces between the teeth. As the wheels turn, the liquid is carried around as shown by the arrows.

carries it to an opening. The water runs forcibly from the opening.

One kind of centrifugal pump contains revolving blades, like the blades of a turbine. Another kind contains a screw which forces water along. These pumps are used in most city water systems, in irrigation systems, and in the automobile cooling system.

DEMONSTRATION. HOW DO MODEL MACHINES OPERATE?

What to use: Model force pump, model water wheel, model turbine, model windmill.

What to do: Set up and operate the model machines.

What was observed: Describe briefly the operation of each machine.

What was learned: Classify the parts of each machine as simple machines. State how force was applied to each cause.

Exercise. *Complete the following sentences:* Machines cannot save —1—, but can apply —2— to save us the need of using our muscles. Force can be applied to revolving —3— or to a —4— operating within a cylinder. Force of —5— water or the force of expanding —6— may be applied to do work. The outward push or pull of a rotating body is called —7—. This force is a special form of —8—. The most efficient machine for applying water power is the —9—.

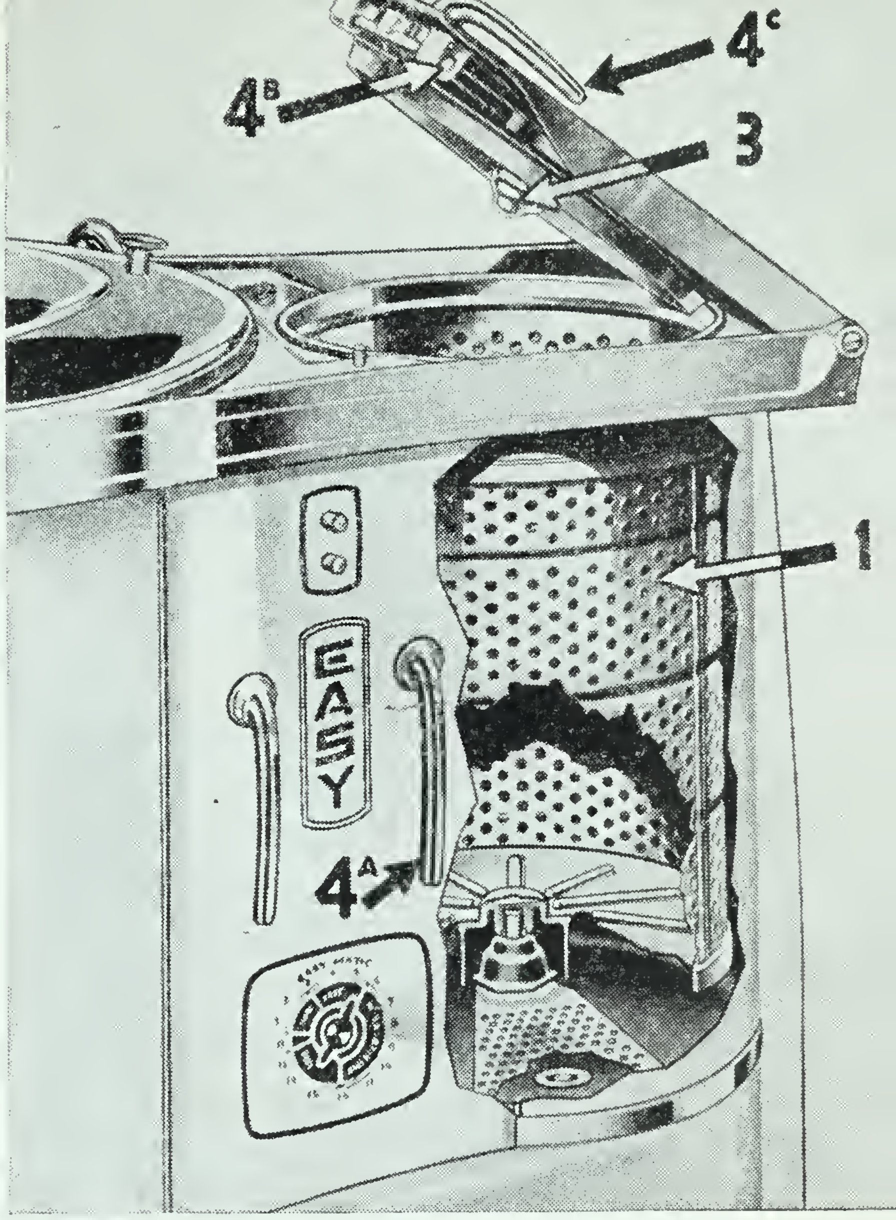
Science activity. Make models of one or more of the following machines: a) A turbine, using tubing, a shoe-polish can, and metal blades held in a cork. b) A pump, using a glass tube, a stopper, and inner-tube rubber for valves. c) A water wheel, using either wood from apple boxes or metal from cans. d) A windmill, using metal, wood, and wire, mounted on a wooden frame. Use coat-hanger wire for shafts. e) A windmill to operate a lift pump. Construct the windmill so carefully that when you set it before a fan, the pump will pump water.

4. What machines do we use in the home?

Although few women realize it, they actually use more machines in the home than are used in many businesses. In fact the modern home is to a large extent a machine shop. Some of the common household machines are the washing

machine, the vacuum cleaner, the electric refrigerator, the electric mixer, the sewing machine, the piano, the ironer, and the clothes drier. Scientific progress makes housework easier and makes the home a more healthful place in which to live.

How does the washing machine work? There are several types of washing machines on the market, many of which are dependable in their operation. There are both different kinds of power mechanisms and different types of washers. The commonest type of tub is round and contains a set of modified paddle wheels which agitate the water. After the water has been circulated in a certain direction for a short distance, the direction of the force is reversed by a gear arrangement, and the clothes are swished through the water against the direction of the current. The new current is established just as the direction of movement is again reversed. Another type of washer is made of one tub, perforated on all sides, inside another. This tub is spun around and reversed in direction at short, regular intervals. In some machines the tubs are whirled in irregular paths inside a second tub.



Courtesy Easy Washing Machine Corp.

Clothes put into the perforated inner cylinder are whirled dry because of centrifugal force. The spinning tub is shown by 1; numbers 4^A, 4^B, and 4^C are safety catches; and 3 is a device which prevents the drier being opened while the spinner is in motion.

Power is provided by gasoline engines, electric motors, or by hand-operated cranks.

The two types of clothes driers which are safe to operate are not wringers. One of these driers, the spinner type drier, consists of a perforated inner tub which dries the clothes by

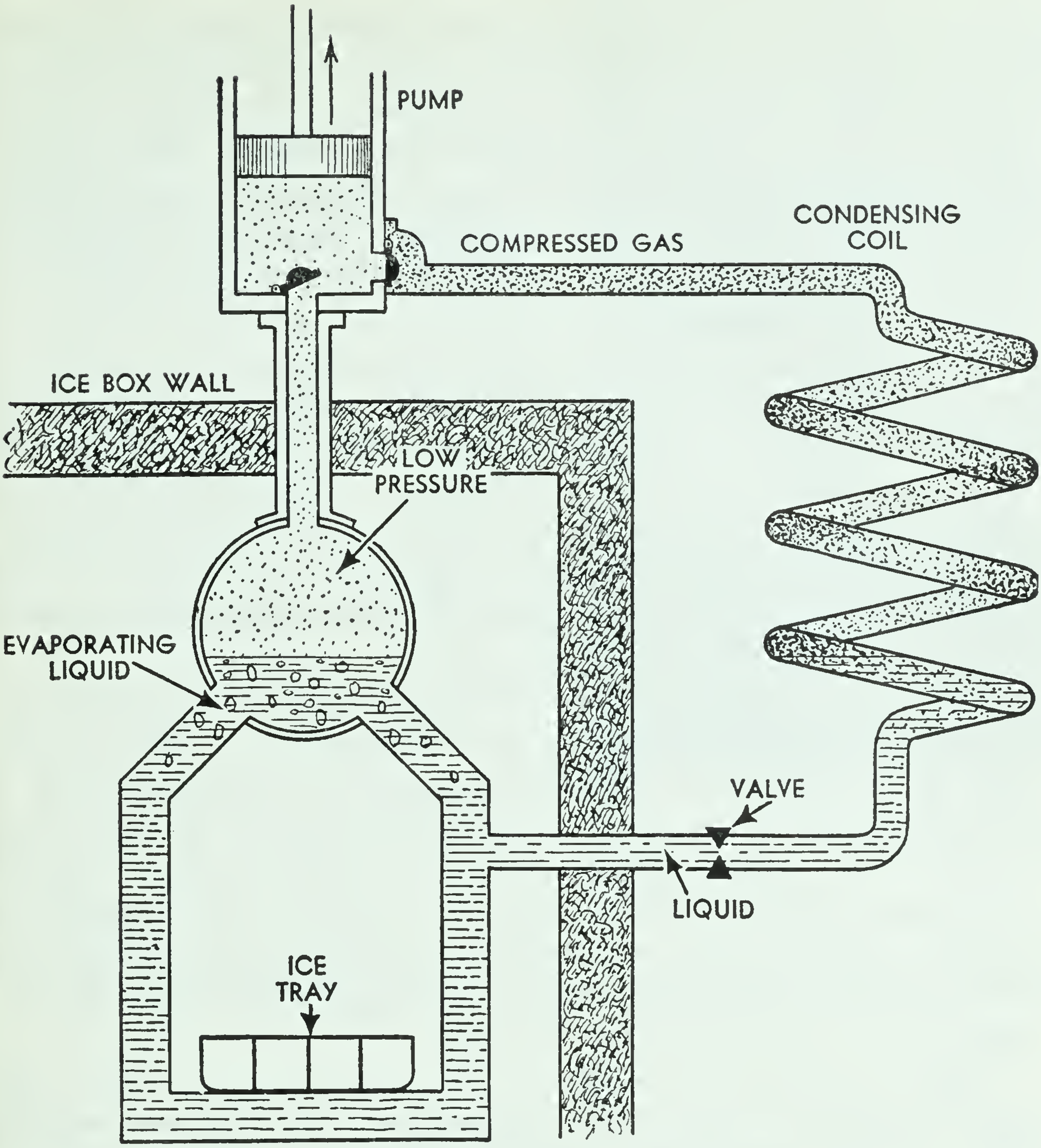
centrifugal force. Another type of drier operates by air pressure and consists of a pan with a tightly fitting lid. Inside the lid is a rubber disk which is fitted tightly to the lid. Air is blown in, just as a football bladder is inflated. The inflation squeezes the water evenly from the clothes, which are held in a wire basket to let water run out easily. The ordinary roller-type wringer is one of the most dangerous devices in the home, and although it dries clothes almost as well as the spinner type, its use cannot be encouraged from a safety standpoint.

How does the vacuum cleaner work? There are two types of vacuum cleaners on the market and in general use. One type has a fan and motor which are mounted on wheels, and the complete cleaner is rolled over the rug. The fan reduces air pressure in the elongated nozzle and moves the air under pressure into the dust bag. The dust bag is a closely-woven sack with a fleeced inner finish. The fibers filter the dust from the air as it passes through the bag. Some cleaners are equipped with brushes which are rotated by the motor; some have brushes which are rigidly held against the rug; and still others have no brush.

The second type of vacuum cleaner consists of the same parts as the first. However, the motor, fan, and dust bag are situated in a portable, tanklike container, and are set upon the floor. From the fan there is a long tube to which a nozzle is attached to pick up dust. This type of cleaner is advertised as being lighter to operate than the one in which all the mechanism is moved.

The best models of the two types of vacuum cleaner are equally effective in doing their work. The only way to test a vacuum cleaner is by actual use under standard, laboratory conditions. The tests conducted by the salesmen are not scientific, for they do not compare one cleaner directly with another, nor do they perform all types of cleaning. Each salesman makes only the tests which permit his machine to show up well.

Electric vacuum cleaners are dangerous, in that they frequently become worn, and either the motor or cord may become grounded. This situation offers a serious shock hazard. No other electrical machine is so likely to be handled



The electric refrigerator consists essentially of a pump and two coils. In the coil inside the box low pressure causes a liquid to boil. In the coil outside the box high pressure causes a gas to condense. Heat is transferred from the box in the process.

with one hand while touching with the other hand a grounded connection, such as a radiator or water pipe.

The vacuum cleaner is the only satisfactory device for cleaning rugs. Fewer bacteria enter the air and less dirt is left in the rug when a vacuum cleaner is used than when any other cleaning method is used. Because sand is removed, the rug wears better.

How does the refrigerator work? The ordinary icebox is

not a machine. It is merely an insulated container. The electric refrigerator, on the other hand, is a combination of several common devices. One, of course, is an electric motor which furnishes power. Another is some type of force pump.

Anyone who can remember how cooling and heating affect evaporation of liquids can understand how the refrigerator works. You are already familiar with all the principles involved in its operation.

The actual cooling takes place in the cooling unit, which is a coil of pipe. Inside the coil a liquid is permitted to flow and evaporate. When liquids evaporate, heat is absorbed. The heat absorbed comes from the inside of the refrigerator and the articles in it. The pressure in the coil is kept relatively low by a pump which constantly pumps out the gas as it is formed. The low pressure causes the gas to evaporate rapidly and speeds up the cooling process.

The pump collects the gas from the coil and compresses it. The gas becomes warmer as it is compressed. The coil containing the warm gas under pressure is cooled, either by a stream of water or by air moving through radiating vanes on the coil. As the gas is compressed and cooled, it gives off enough heat that it changes to a liquid. The pump and coil for cooling the compressed gas are located outside the refrigerator. The heat which was originally inside the refrigerator is carried to the outside.

When the liquid is cooled, it trickles through the valve into the cooling coil inside the refrigerator and is again changed into a gas by absorbing heat from the interior of the box.

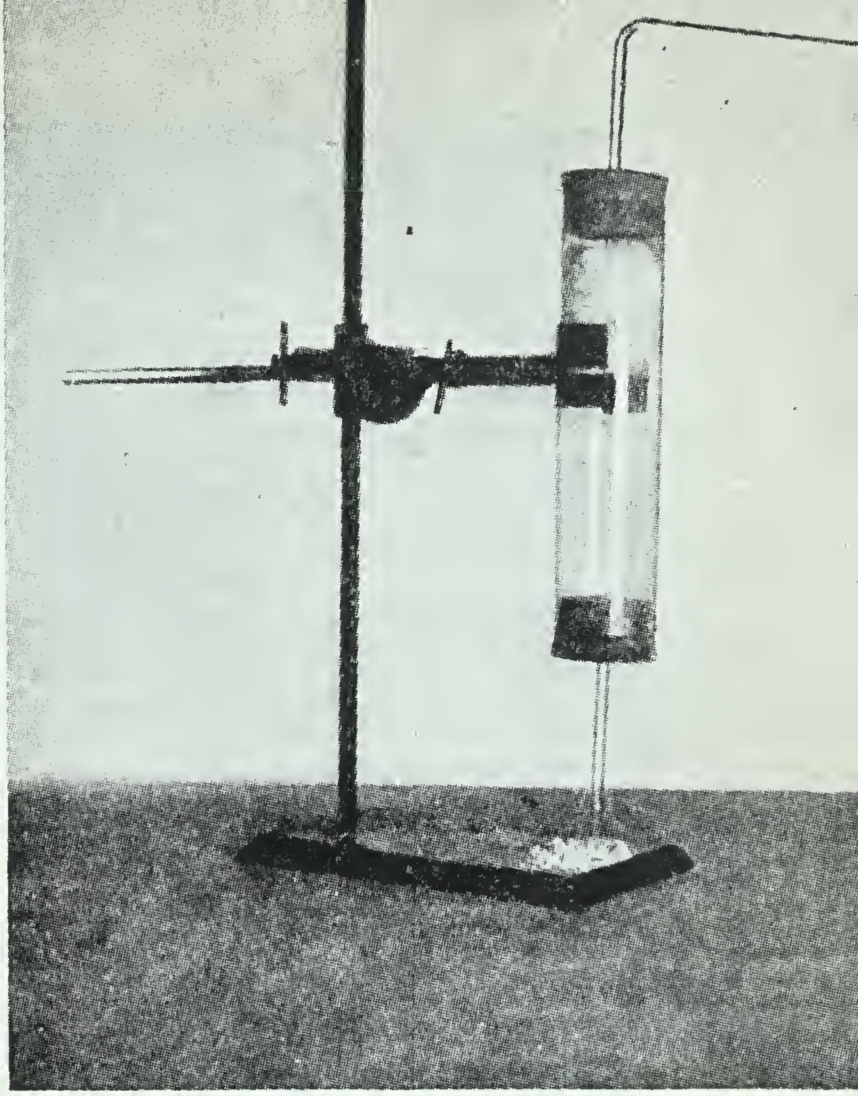
There are two types of pumps in common use: the piston type of force pump and the rotary force pump. Both work satisfactorily in the better models of refrigerators.

The coil inside the box becomes covered with ice, as moisture from the food condenses on the cold coils. The ice formed is an insulator. To get rid of the coating of ice, it is necessary to shut off the current once a week and let the box warm up enough to melt off the ice. A pan is set under the freezing unit to catch the falling water and ice. This process is called defrosting.

The construction of the icebox is of utmost importance in

the proper operation of the refrigerator. The walls must be waterproof, easily cleaned, and strong. Between the walls insulation is placed to exclude heat. The door is fitted tightly with rubber gaskets to seal all cracks. The air circulates in the icebox, falling below the cooling coil and rising along the outside walls.

The commercial ice machine, although not a household device, is essentially a big electric refrigerator unit. It is used to freeze ice cubes much larger than those frozen in the home refrigerator, but the principle of freezing is the same. The ice blocks are generally frozen in tanks. The tanks are in a vat of salt water, through which the freezing coil pipes run to chill the salt water or brine. Much of the ice delivered in our homes is made by ice machines.



This apparatus may be used to illustrate the principle of the vacuum cleaner.

Demonstration. How Do the Vacuum Cleaner and Refrigerator Work?

What to use: Air pump, lamp chimney, stoppers to fit, glass tubing, flour, bell jar, plate, watch glass, cork, ether.

What to do: Set up the lamp chimney as shown in the picture. With the mouth or air pump withdraw air sharply from the upper tube.

Set up the air pump to exhaust the bell jar. On the plate put a cork. Wet it, and put the watch glass on the wet cork. Fill the watch glass with ether, and cover with the bell jar. Pump air from the bell jar until the ether boils away. Quickly examine the watch glass and cork. (*Do not have a flame or an electric motor in operation near the ether.*)

What was observed: Describe what you saw in each part of the demonstration.

What was learned: Explain why the two observed results took place.

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* air pressure, fan, pump, evaporation, dust bag, cooling, condensation, gives off heat, shock, ice, defrost, insulation, motor, force pump.

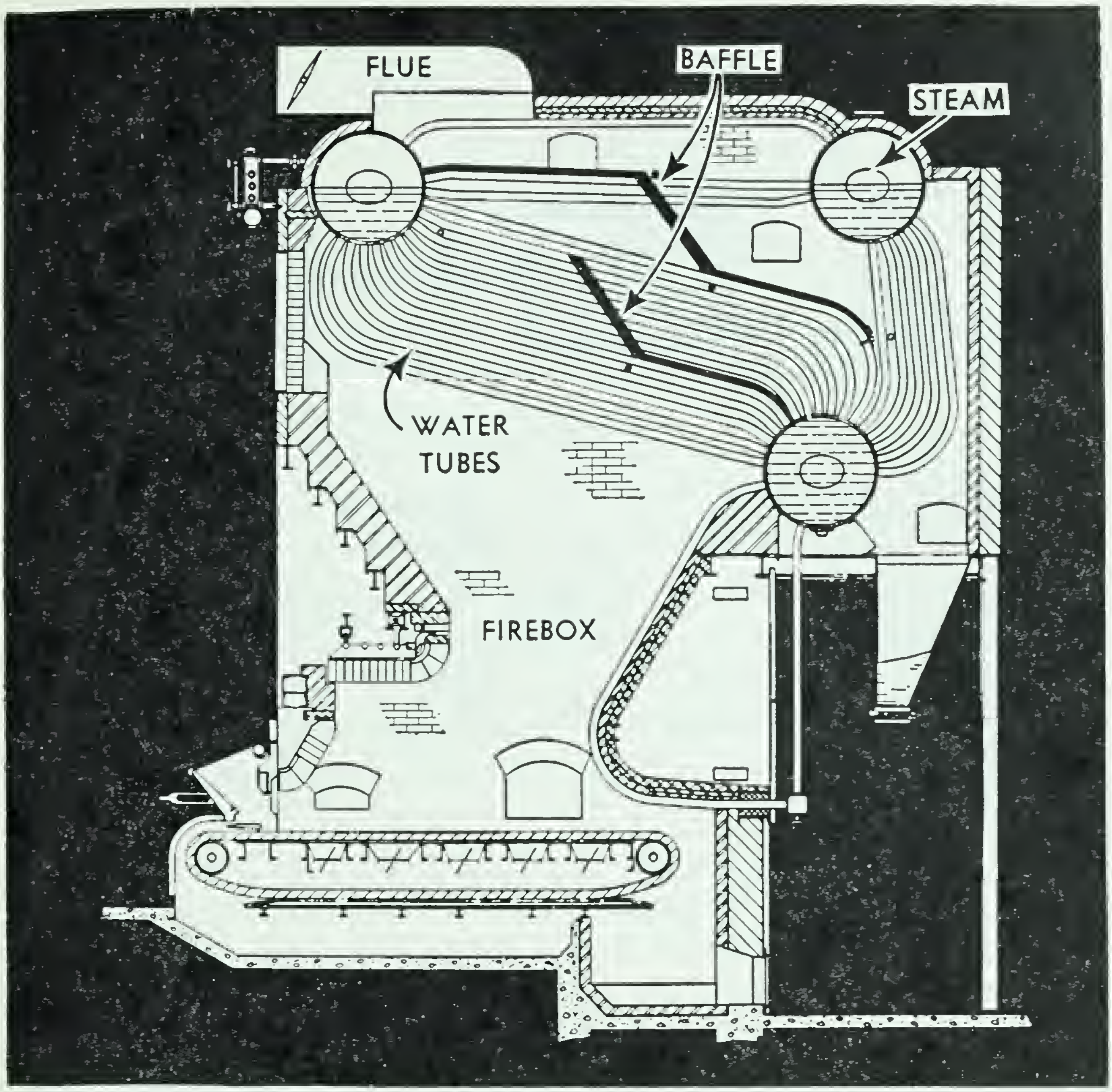
Science activity. Learn thoroughly the operation of every machine in your home. Study the booklets that explain the care and operation of the machines.

5. How is steam used for power?

Because we do not have steam engines in our homes and do not see them in small shops and factories, most of us do not realize the great value of steam in providing power for modern industry. Yet you know that coal is our most important source of power. We cannot use coal directly in engines. The coal is used to produce steam, which in turn operates the steam engine or the turbine.

The steam engine is a fairly simple engine. It has few moving parts, and these are large and strong. It does not have the complex timing devices or the many pistons and cylinders of the gasoline engine. It is simpler to operate and repair than other engines. The turbine is still simpler in principle and operation than the steam engine. The ordinary engine is not very efficient, for it uses only about 10 per cent of the energy in the coal to do work. The steam turbine is considerably more efficient than the steam engine. Even so, ordinary engines are cheap to operate, for it is said that a modern freight locomotive can haul a ton of freight a mile with a handful of coal and a glass of water.

How is steam generated? Steam is generated in a boiler. The usual commercial boiler is heated by a stoker-fired, or blower-fired, coal burning furnace. Tubes of water run through the flames to absorb maximum heat. The greater the amount of surface exposed to the hot gases, the more efficient is the heating. Some small boilers have fire tubes—that is,



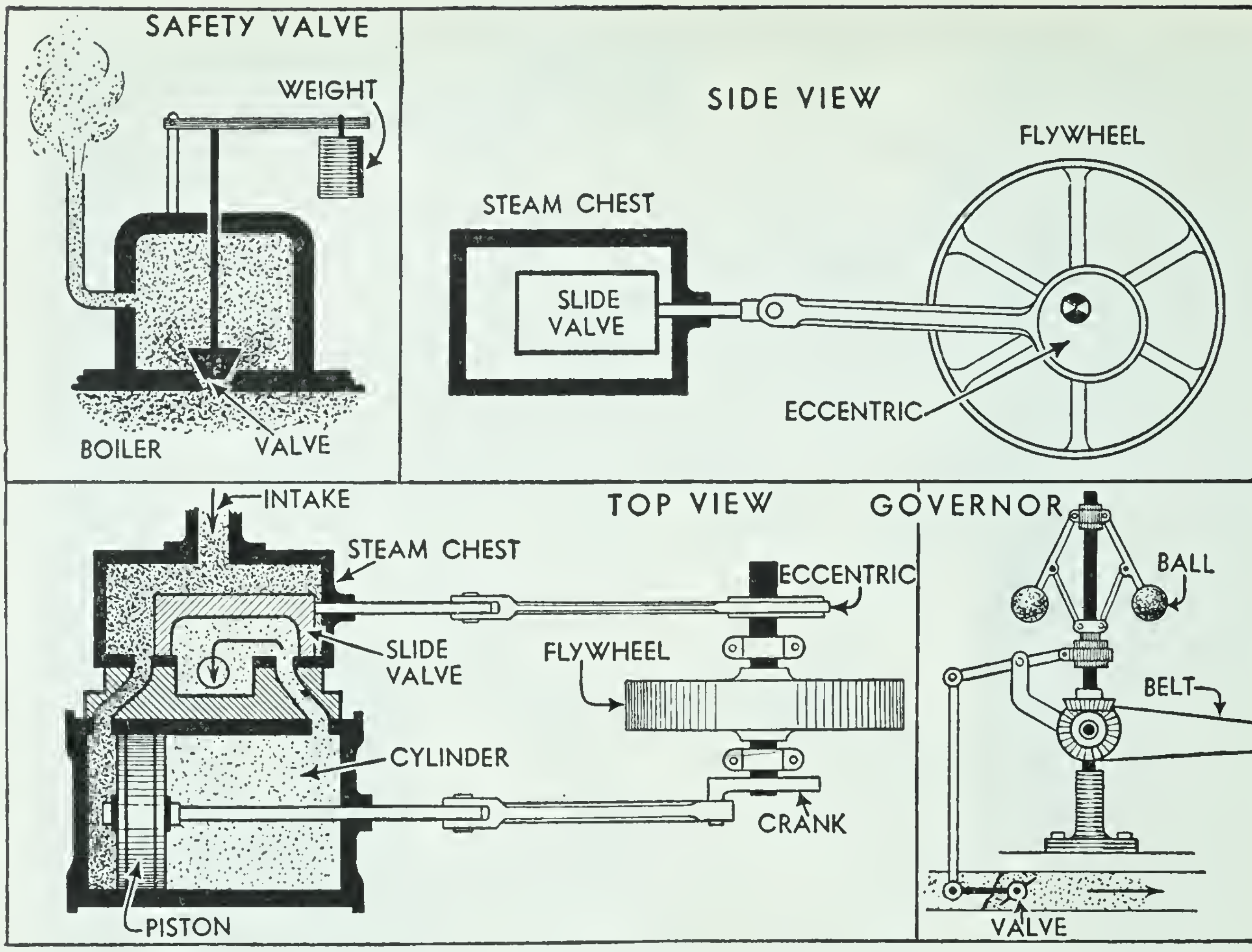
Courtesy Union Iron Works

Steam is generated in a boiler. The flames pass around the baffles and through the water tubes to get all the heat from the fire that is possible. The object of the pipes is to increase the heating surface.

the hot gases go through tubes which are surrounded by water.

When water changes to steam, it increases in volume 1600 to 1700 times. Steam boilers produce high pressures. For use with small turbines, it is common to employ a steam pressure of 400 pounds per square inch. To attain this pressure, the water and steam are heated to 450 degrees Fahrenheit. Steam which is so hot and under such great pressure is completely dry and acts as a gas.

How does the steam engine work? The steam engine is the oldest of the modern machines for applying force effec-



Can you tell in what parts of the diagrams the steam is under high pressure? Study these diagrams until you can explain the function of each part that is named.

tively. It was not invented by any one person, but the man who did most toward its development was James Watt. He improved an engine, invented by Newcomen in 1705, by adding better valves and a governor. The steam engine is largely responsible for the industrial revolution which brought about our machine-type civilization.

The operation of the steam engine is comparatively simple. The steam is lead from the boiler through a pipe to a regulating valve called a throttle. When the throttle is open, steam enters the steam chest, a boxlike structure on the engine. From the steam chest there are two openings into the cylinder, one entering at each end. These openings are called ports. Inside the steam chest is a slide valve, which is in such a position that one or the other of the ports is always closed. Other types of valves are used in steam engines, also.

The steam under pressure enters the intake and passes through one of the ports to the cylinder. When the pressure

of the steam is exerted upon the piston, the piston moves, operating a crank attached to a shaft. The shaft is turned. As the shaft is turned, an eccentric (a wheel off center) turns in such a way that it changes the position of the slide valve. Steam under pressure is then admitted to the other end of the cylinder, and the piston moves back. The steam in the cylinder behind the piston escapes through the port covered by the slide valve and passes out of the engine through a pipe called the exhaust.

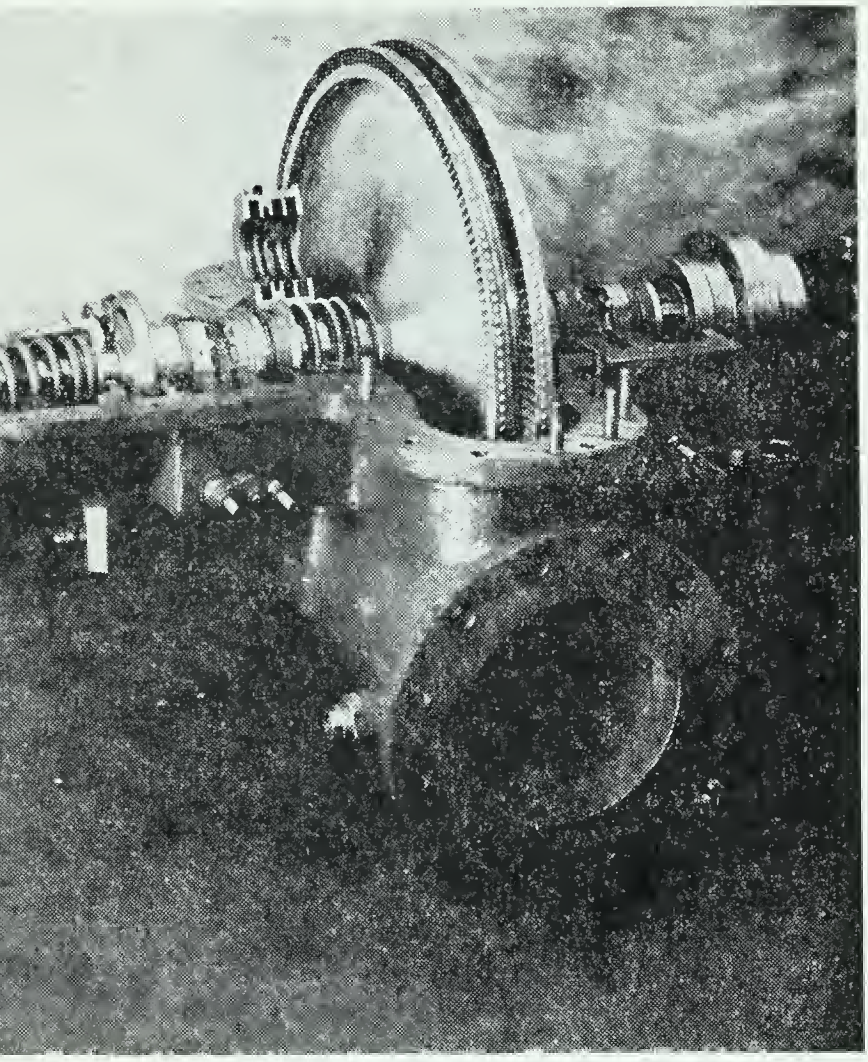
The purpose of the slide valve is to permit the steam to enter the ports alternately and to permit the steam enclosed in the cylinder to escape when it has done its work.

The flywheel is used to give the engine a constant speed. The flywheel has a heavy rim and moves steadily because of its inertia. When the piston reaches the end of the cylinder, the steam exerts no pressure for an instant. The inertia of the flywheel carries the piston beyond this point and insures the desired even speed. To start an engine, it is sometimes necessary to turn the flywheel to get the piston into a center position.

There are two devices designed to increase the safety of a steam engine. One is a safety valve. The safety valve in the diagram on the opposite page is the simplest possible kind. Often a spring is used instead of a weight. When the pressure of the steam in the boiler becomes sufficient to force the valve open, the pressure is reduced as the steam escapes or "pops off." The safety valve prevents accumulation of pressure sufficient to explode the boiler.

The governor regulates the speed of the engine. It is located upon the intake pipe and controls the amount of steam that enters the steam chest. It consists of two balls, as shown on page 374, which are turned by a belt connected to the shaft on which the flywheel turns. The faster the balls turn, the more they are separated by centrifugal force. As they separate, they pull a lever which partially closes the steam valve. As the valve closes, less steam enters, the speed of the engine decreases slightly, and the balls fall to a lower position, causing the valve to open again.

What are double and triple expansion engines? The double or triple expansion engine consists of a series of two or



Courtesy De Laval Steam Turbine Co.

This small steam turbine is used to provide power for pumping water into a boiler. The upper part of the casing has been removed to show the rotating wheel with its many vanes.

three cylinders, side by side, each larger than the one before it. Steam under great pressure is led to the first cylinder. After the steam has been used in the first cylinder, it is led to a second cylinder and may in turn be led into a third cylinder. Steam is finally condensed and returned to the boiler by a pump. Such engines are more efficient than the single expansion engine.

What are the uses of steam engines? Many of the nation's fastest passenger trains, and almost all the ordinary trains, are pulled by steam locomotives. The locomotive has two engines, one on each side, so placed that one is always in starting position. Many factories, sawmills, electrical generating plants, ice plants, and pumping stations depend upon the steam engine for power.

How does the steam turbine work? The steam turbine is the same in principle as the water turbine. There is a series of nozzles, controlled by valves and a governor, through which steam enters the turbine. The steam strikes a wheel upon which there are many vanes or buckets. The steam is directed from the first set of vanes to the second by a set of stationary, or immovable, vanes. The steam turned by the stationary vanes pushes upon the second set of rotating vanes. There may be only two, or there may be a large number, of these sets of vanes. The entire working part of the turbine is enclosed in a heavy casing of steel. No steam can go through the turbine without doing work on the vanes.

The operating speed of the turbine is ordinarily rather

high, speeds of 3600 revolutions per minute being common practice. The speed is determined by pressure of steam, size of the turbine, the load it is carrying, and the way the governor is set.

Turbines are used in steamships, particularly those large enough for ocean voyages. The disadvantage of the turbine in being unable to reverse makes it impractical for use in locomotives. Practically every large steam power plant in which electricity is generated employs turbines for power. They are ideal for this work, for the whirling motion of the turbine is carried by a shaft directly to the dynamo, which generates the electricity by the whirling of its coils through a magnetic field.

Turbines have dozens of industrial uses. They are valuable for pumping water and supplying power for factories. Blowers in large ventilation systems are economically operated by power from turbines. To reduce speed of turbines, gears may be used effectively.

DEMONSTRATION. HOW DO STEAM ENGINES WORK?

What to use: Toy steam engine, cross-section model of engine, model turbine, model governor.

What to do: Operate the toys and models, observing carefully how each part does its work.

What was observed: Compare your observations with the description in the text of the operation of large engines and turbines.

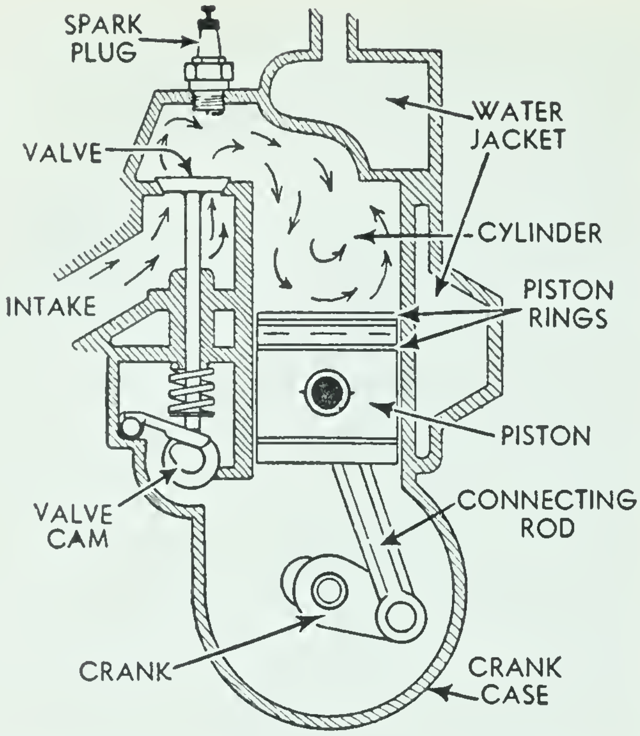
What was learned: State the principles upon which these engines operate.

Exercise. *Make a drawing of the piston, cylinder, slide valve, and steam chest, as shown in the diagram on page 374, but with the piston and slide valve at the opposite ends of their strokes.*

Science activity. Make a cross-section model of a steam engine, using heavy cardboard or plywood. Make it in such a way that the slide valve and piston will move.

6. How do the fuel-burning engines work?

The steam engine and turbine are sometimes called external combustion engines because the fuels are not burned in the engines, as is true in internal combustion engines,



The gasoline engine is complex. Study the diagram until you can explain the function of each part labeled.

but in a furnace under a boiler. There are two types of internal combustion engines: the gasoline engine and the Diesel engine. Both of these engines burn their fuel inside the cylinder itself.

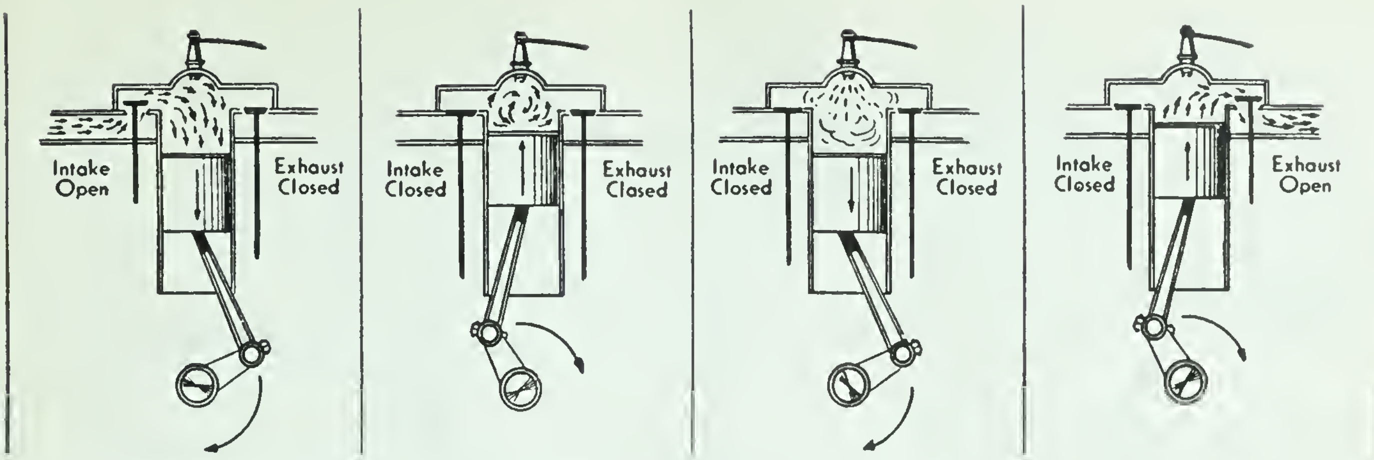
Internal combustion engines start instantly, without a period of waiting to generate steam. They are generally lighter and more portable than the steam engine and use a more compact type of fuel. These engines are somewhat more efficient than the ordinary steam engine but less efficient than turbines.

What are the uses of internal combustion engines? There are about 30 million automobiles in the United States equipped with gasoline engines. All except a few experimental airplane engines are gasoline engines. The farm tractor, particularly the smaller tractor, is built around a gasoline engine as a power unit. The larger tractors are built around Diesel engines.

The small gasoline engine is the power unit for sawing wood, pumping water, generating electricity, and running washing machines. There are farm washing machines on the market with a small gasoline engine built in. The outboard motor is a gasoline engine.

Internal combustion engines are a serious source of danger from carbon monoxide poisoning and must never be operated in a closed room under any conditions, unless the exhaust fumes are carried by an absolutely gas-tight pipe to the out-of-doors. Even then, fatal amounts of carbon monoxide may leak past the piston of the engine into the room.

How is fuel admitted to the gasoline engine? If liquid gasoline is run into the cylinders, the engine does not start. When this happens, the engine is flooded. The fuel must be changed to a fine spray or vapor and mixed with exactly the



Courtesy General Motors Corporation

The gasoline engine operates in four strokes or cycles. These strokes, left to right, are intake, compression, power, and exhaust. Note the position of the piston and the action of each valve during each of the strokes.

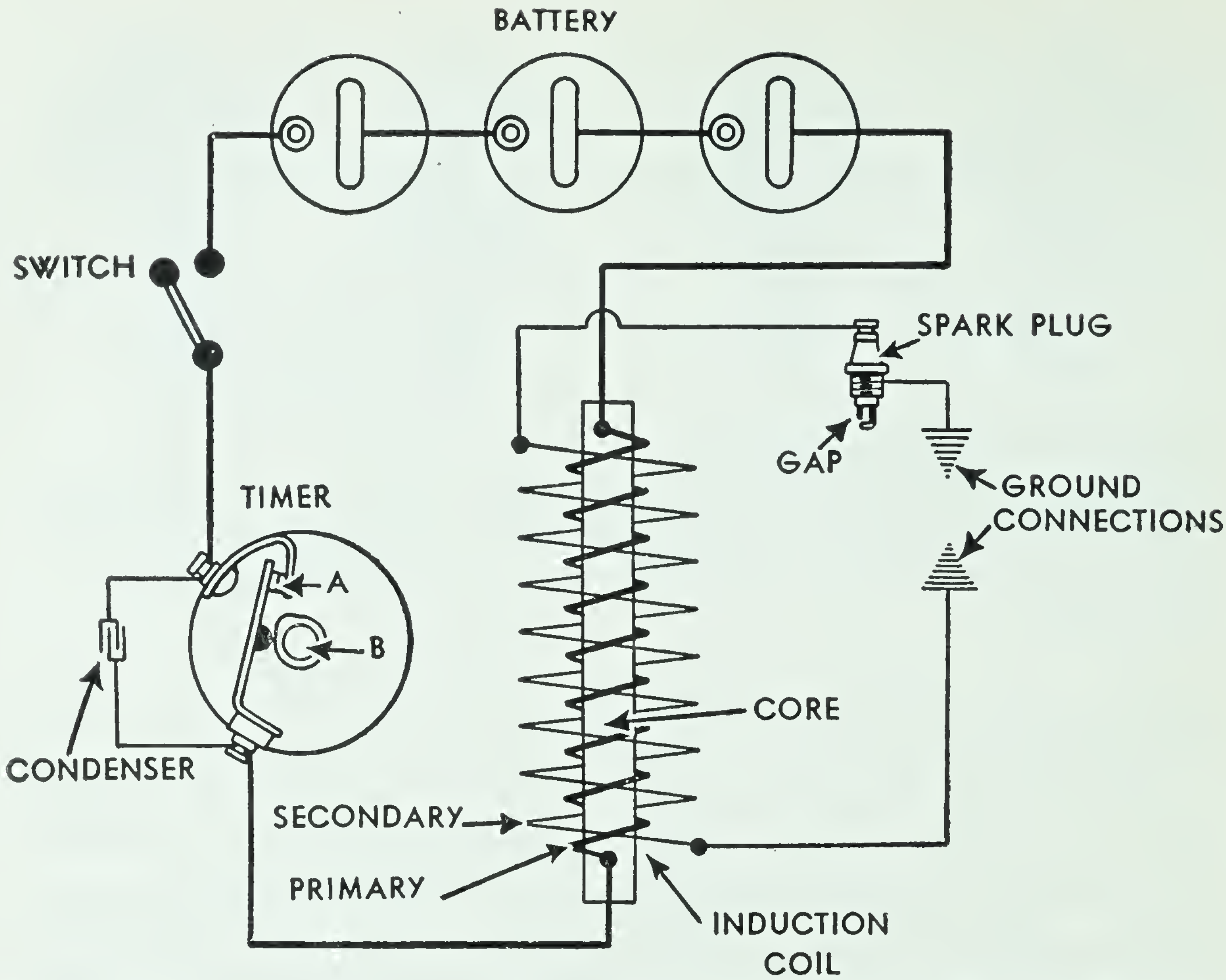
right amount of air. By volume, from 40 to 60 parts of air to one part of gasoline are used.

The device which mixes the gasoline with air is the carburetor. It consists of a cup into which gasoline is forced by air pressure or gravity from the tank. The valve at the outlet of the cup is called a needle valve on account of the fact that the small opening is partly closed by a needle-like rod. The gasoline is sprayed from the needle valve into a pipe through which air flows. The gasoline is partially evaporated by the air and by the heat of the engine. The valve of the carburetor is controlled by a float and by a screw type of control.

What is the spark? The gasoline is ignited in the cylinders by an electric spark. The current from the magneto or storage battery is stepped up by an induction coil to about 14,000 volts. This current jumps across the gap in a spark plug to cause a spark. The time at which the spark is produced is controlled by a timer operated by the action of the engine.

What are the four strokes of the engine? Practically every gasoline engine in use today is the four-cycle type. That is, there are four strokes of the piston, of which only one produces any power. The flywheel makes two complete revolutions while the piston is going through the four cycles.

The *intake stroke* pumps fuel from the carburetor into the cylinder. There are two valves on each cylinder. One admits fuel and air; the other lets out, or exhausts, burned gases. The intake valve is opened by a rod operated by the cam.



When the switch is closed, the current in the primary coil magnetizes the core and builds up a charge in the condenser. When the cam **(B)** opens the contact points **(A)**, the powerful current is induced in the secondary circuit, causing a spark to jump the gap. The cam is turned by a gear on the crankshaft.

The intake stroke makes a vacuum in the carburetor, which causes the flow of fuel. The piston moves downward on the intake stroke, and fuel is admitted to the top of the cylinder.

The upward or *compression stroke* of the piston compresses the mixture of gasoline and air. The temperature rises to 400 or 500 degrees Fahrenheit. Both valves are closed. The total pressure may be more than 100 pounds per square inch.

At the beginning of the *power stroke,* the spark is sent through the mixture of gasoline and air just before or at the instant that the piston is carried by the energy from the flywheel past the end of the compression stroke. The fuel burns so rapidly that an explosion results, and the piston is forced downward violently. The power is carried through a lever called a connecting rod to the crankshaft. The pressure within the cylinder may be 700 pounds per square inch.

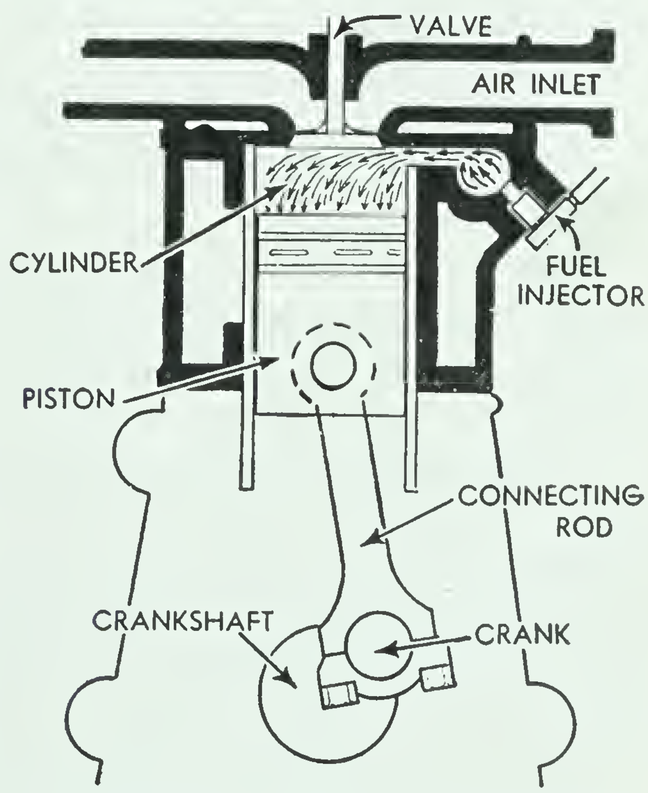
The piston is moved up on its fourth or *exhaust stroke* by the energy from the flywheel and other pistons. The exhaust valve opens, and the piston, acting as a force pump, blows the burned gases from the cylinder through the exhaust pipe.

In the four-cylinder engine power is applied once each half revolution of the flywheel. The use of a larger number of cylinders increases the smoothness of the operation of the engine.

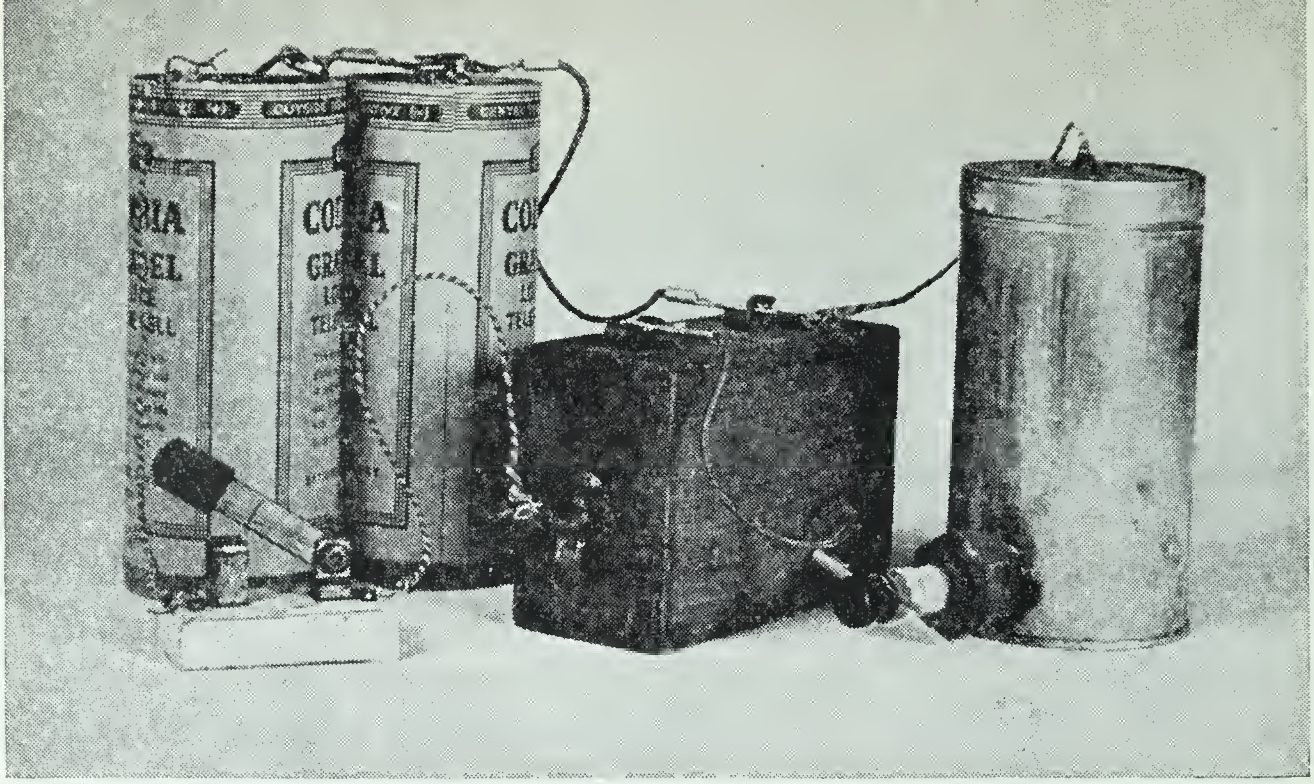
The engine must be started by some force outside itself, either a hand crank or an electric motor starter. The cranking pumps fuel into the cylinder, compresses it, and causes the spark to ignite the charge. The engine is lubricated by heavy lubricating oil and cooled by circulation of air or water around the cylinders.

How does the Diesel engine work? Although the Diesel engine is a four-cycle internal combustion engine, it differs from the gasoline engine in several important respects. First, it burns fuel oil instead of gasoline, which makes it more economical. Second, it has no spark plugs or carburetor. Third, it does have a fuel injection pump.

On the intake stroke, the piston moves down, and a valve admits only air. On the upward stroke, the air is compressed to about 500 pounds per square inch, which raises the temperature of the air to about 1000 degrees. At the instant the compression is greatest, the injection pump shoots a drop of oil—ranging from the size of a grain of wheat to the size of a large bean—into the cylinder. This process takes about 1/4000 of a second. The oil immediately vaporizes and burns. The power and exhaust strokes are similar to those of the gasoline engine.



The Diesel engine is simpler in construction than is the gasoline engine. Study this and the diagram on page 378 until you know the difference between the two engines.



This setup illustrates the principle of the gasoline engine. The parts shown are a spark plug, can, induction coil, battery, and switch.

Diesels that are too small are not practical or economical to operate. Heavy tractors are almost always Diesel operated. So are some trucks and busses. There are many small power plants which employ Diesel engines to produce electricity or pump water. Some trains derive their power from Diesel engines.

Demonstration. How Does the Gasoline Engine Work?

What to use: Induction coil, battery, spark plug, tin can with lid, gasoline or ether.

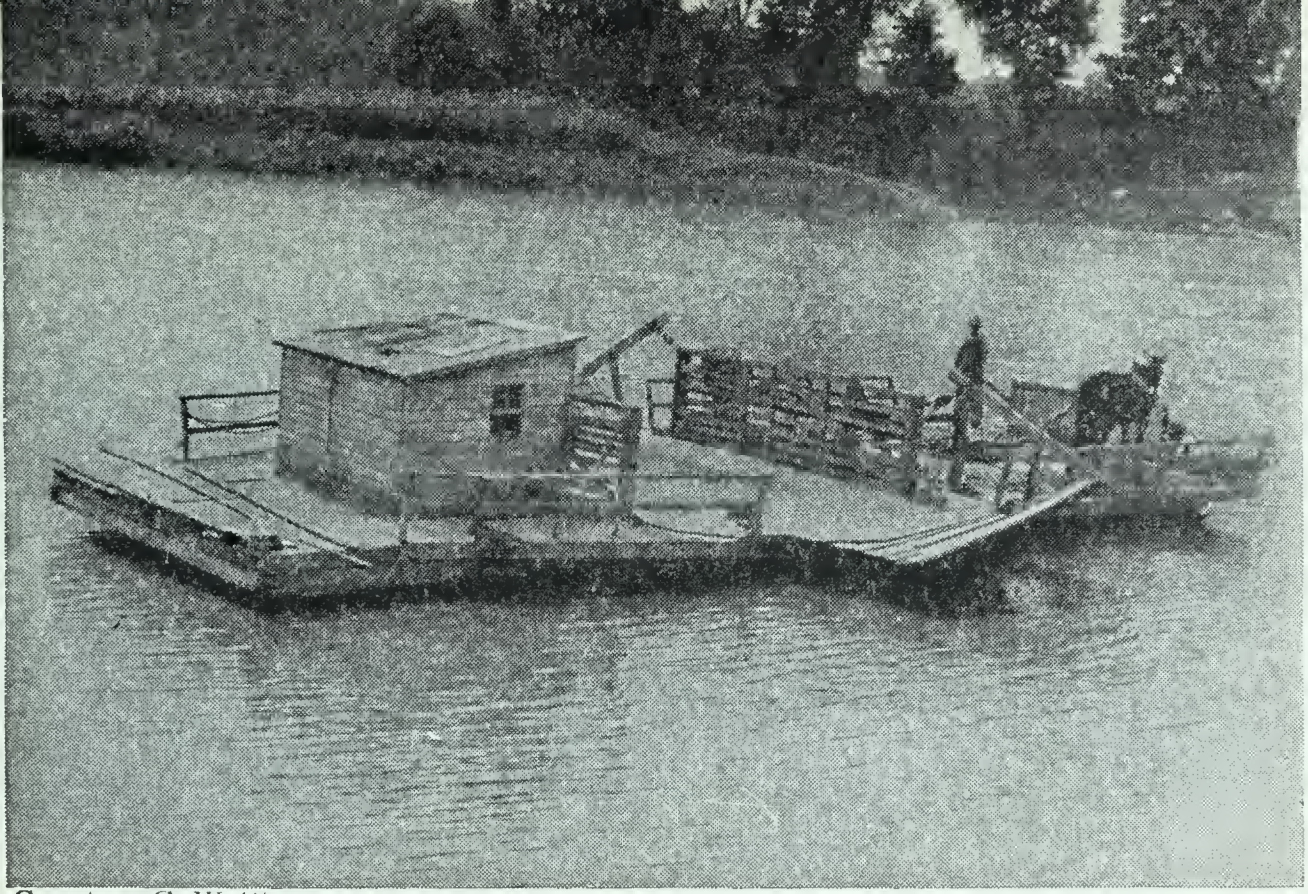
What to do: Cut a hole in the side of the can, and screw the spark plug into the hole. Attach the wires, as shown in the illustration, one to the plug and one to the cover of the can. Do not attach the wires from the coil to the battery until directed.

Put two drops of ether or gasoline into the can, and close the cover. Give the liquid time to evaporate. Evaporation can be speeded by warming with hot water. (*Close and remove the fuel container.*) Stand back, and connect the battery. If no explosion results, use less fuel or warm the can more thoroughly. (*This demonstration should be done only in a well-ventilated room.*)

What was observed: Describe the results of the experiment.

What was learned: What principles are used to cause an explosion of gasoline in a cylinder?

Exercise. *Complete the following sentences:* The gasoline and —1— are mixed in the —2—. The mixture is admitted to the —3—, where it burns. The gasoline engine is called an —4—



Courtesy G. W. Sturm

This old ferry boat actually has a one-horsepower motor. The horse walks around in a circle, turning the crank which operates a paddle wheel. This horse does not produce work at the rate of 33,000 foot-pounds per minute, however. Only large, strong horses can do work at the rate of one horsepower.

type. The fuel passes through the intake valve on the —5— stroke. On the —6— stroke the piston moves up, and both valves are closed. The spark jumps the gap in the —7— and ignites the mixture. The exhaust valve is open, and the piston moves up on the —8— stroke. The Diesel has no —9— or —10— as the gasoline engine has but does have an —11—. The fuel oil is ignited by —12—.

Science activity. Using a bottle, cork, wire, and boards, make a model piston, cylinder, connecting rod, and crankshaft.

7. What are some machines used in agriculture?

Many of the machines used in agriculture are simple tools, such as the hoe, shovel, rake, and hand cultivator. But today most farming is done with modern machinery, operated by electric motors, steam or gasoline engines. Before we can understand properly the need of using power machines, we should understand better the meaning of power.

What is power? Power is work done in a definite amount of time. When we measure work, we multiply the distance in feet through which the force acts times the force in pounds. The result is the number of foot-pounds of work done by the machine. To measure power, we consider the amount

of time taken to do the work. That is, power equals work divided by time, or:

$$\text{Power} = \frac{\text{Force} \times \text{Distance}}{\text{Time}}$$

The unit for measuring power is the horsepower. Although there are many horses found on farms today which are strong enough to pull with enough energy to produce one horsepower, the average horse cannot produce work at this rate. A horsepower was defined by its inventor, James Watt, as work done at the rate of 33,000 foot-pounds per minute. Expressed as a mathematical relationship, it is:

$$\text{Horsepower} = \frac{\text{Number of feet} \times \text{Number of pounds}}{33{,}000 \times \text{Number of minutes}}$$

In terms of electrical energy, one horsepower is equal to 746 watts.

The production of work in definite amounts of time is essential in agriculture, for seasons do not wait for men. Although a farmer might move his entire crop of wheat by hand if he had a long enough time, practically it is necessary to use machines to harvest crops before they spoil. To apply power effectively, motor driven machines are used on the farm. Cultivators, harvesters, sprayers, milking machines, and many other machines make farm work easier.

How do soil cultivators work? Most of the machines used in cultivating the soil are inclined planes. The common plow has a cutting blade, called the share, and a curved incline, called the moldboard, which lifts the soil and turns it over at the same time. A tractor or horses pull by means of a bar, which may be set at various angles to cause the plow to dig deeply into the soil or to plow a shallow furrow. The furrow is the trench left by turning the soil.

The disk cultivator is made up of many disks of steel sharpened on the edges. The disks are set at an angle to their direction of movement, which makes them inclined planes. They also turn the soil, just as the plow does. The disk cultivator will cut as deeply as a plow does, but does not turn the soil as neatly. These cultivators are used to loosen soil for planting and to kill weeds in soil in which no crop is growing.

Courtesy Caterpillar Tractor Company

By use of power machinery, one man can plant seven acres of land in wheat per hour. How long would a man sowing wheat by hand require to do the same work and do it as well? The machines are grain drills.

The harrow is made up of many spikes or spring teeth, set into a steel frame. Each tooth acts as an inclined plane to cut through the soil which has been loosened by plowing. The harrow breaks up the large pieces of soil into finer particles, needed for successful seeding and holding of moisture.

The seed drill consists of a set of disks or shoes which cut trenches into the soil. Behind each disk is a tube through which grain flows from a box. As the seeds fall into the trench, they are covered with soil by a dragging chain or a dragging bar.

The ordinary garden cultivator is either a small plow or a small harrow, pulled by a horse or pushed by hand. The blades of cultivators are spaced to operate between rows of growing plants.

All soil cultivators encounter large resistances on account of friction. To overcome this resistance, the amount of power required is fairly large.

How do harvesters work? There are many crops to be harvested, each of which requires a different harvester. Grain is harvested by a machine—the combine—which cuts the stalks, elevates the heads into a threshing machine which separates the grain from the chaff, and runs the grain through a chute into a wagon or sack. The threshing is done by run-

ing the heads between revolving cylinders full of spikes. The grain falls through sieves, and the chaff is blown away by currents of air. In other types of harvesters, these operations of cutting and threshing are separated, each machine doing part of the work. Power is supplied by horses, tractors, or steam engines.

Courtesy J. I. Case Company

A machine which is rather recent in its appearance on the farm is the corn harvester. What are the advantages of using this machine instead of harvesting corn by hand?

The potato harvester is essentially a plow to which bars are attached. As the potatoes are plowed up, the soil sifts between the bars, and the potatoes roll along the bars to the ground.

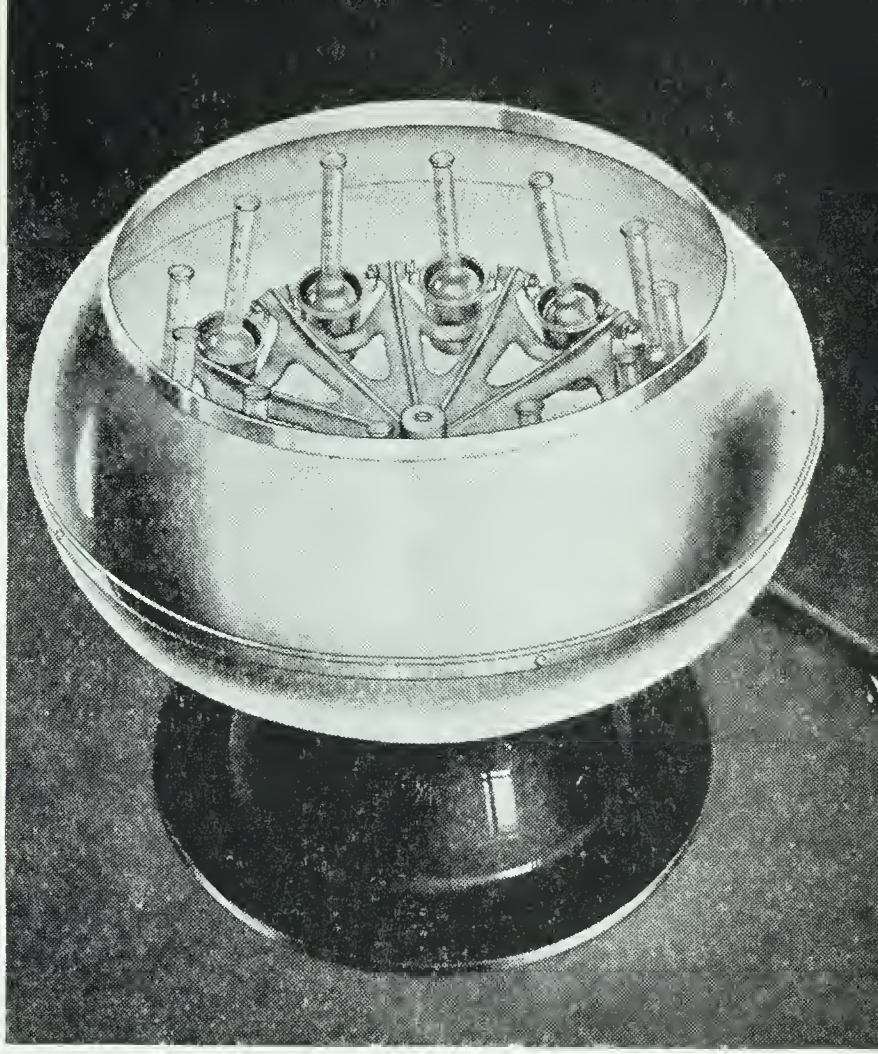
Hay is harvested by cutting it with a mowing machine which drags a sawlike blade along the ground. After the hay is dry, it is raked into rows and lifted, either by hand or by loading machines, into wagons. Hay is usually lifted from the wagon into the barn by a huge fork attached to a cable which turns over a set of pulleys. The pulley is suspended from a track which runs along beneath the roof of the barn. Power is supplied by a horse.

Most of the work of harvesting corn is done by machines. Cotton is harvested by hand, although a successful cotton picker is taking over much of this tedious work.

How do sprayers work? In gardening and fruit growing, the many insect pests can be kept under control only by use of poisonous sprays. These sprays may be applied to small areas by use of a hand-operated, atomizer-type sprayer. For spraying large orchards, the chemicals are mixed and hauled in a tank on a truck or wagon. A force pump, operated by a gasoline engine, pumps the spray from the tank through a pipe and hose arrangement. A fine nozzle breaks the

stream of liquid into a mist so fine that it looks like fog. The pressure required to produce such a spray may be four or five hundred pounds per square inch.

How do the milk separator and tester work? On dairy farms there are many interesting machines. Of these, the milk separator is one of the most important. This machine consists of a tank and whirling bowl containing many cone-shaped metal blades. These blades are whirled rapidly by a crank and gear arrangement. The milk flows from the tank into the bowl. Since cream is lighter in weight than milk, the heavier milk is whirled by centrifugal force to the outer part of the cones in the bowl, and the lighter cream goes to the inner part. The milk and cream flow from the separator through separate spouts. Large separators are operated by motors. Small ones are turned by hand.



Courtesy The Cherry Burrell Corp.

This milk tester is turned by hand. The milk is placed in the slender bottles which are held in the metal tubes. The machine whirls the bottles to separate cream and milk by centrifugal force.

The milk tester is a different type of separator. Milk is placed in slender-necked bottles. Chemicals are added which cause the fat in the milk to be separated from the other materials. The bottles are placed in metal tubes whirled by the gears and crank of the machine. The centrifugal force causes the lighter fat to rise to the top of the whirling bottles. Water is added to the bottles to cause the fat to rise in the neck. The amount of butterfat in the sample may be measured directly by finding the height of the column of fat in the neck of the bottle. The rotating parts of the milk tester are enclosed to avoid the serious danger that would result if a whirling bottle should break loose.

Courtesy the *Minneapolis Tribune*

The milking machine is in use milking a world's champion cow. This Holstein cow produced 20,582 pounds of milk in one year, containing 1252 pounds of butterfat. Does the milking machine make it easier to obtain the milk?

How does the milking machine work? Many large dairies have milking machines. These machines consist essentially of motor-driven air pumps, which reduce the air pressure in a set of tubes. The tubes are placed over the cow's teats, and the machine alternately reduces the air pressure and permits it to become normal. The action of the air pressure causes milk to flow. The milk is collected in metal containers.

Demonstration. What Is the Principle of the Milk Tester?

What to use: Rotator and accessories, muddy water.

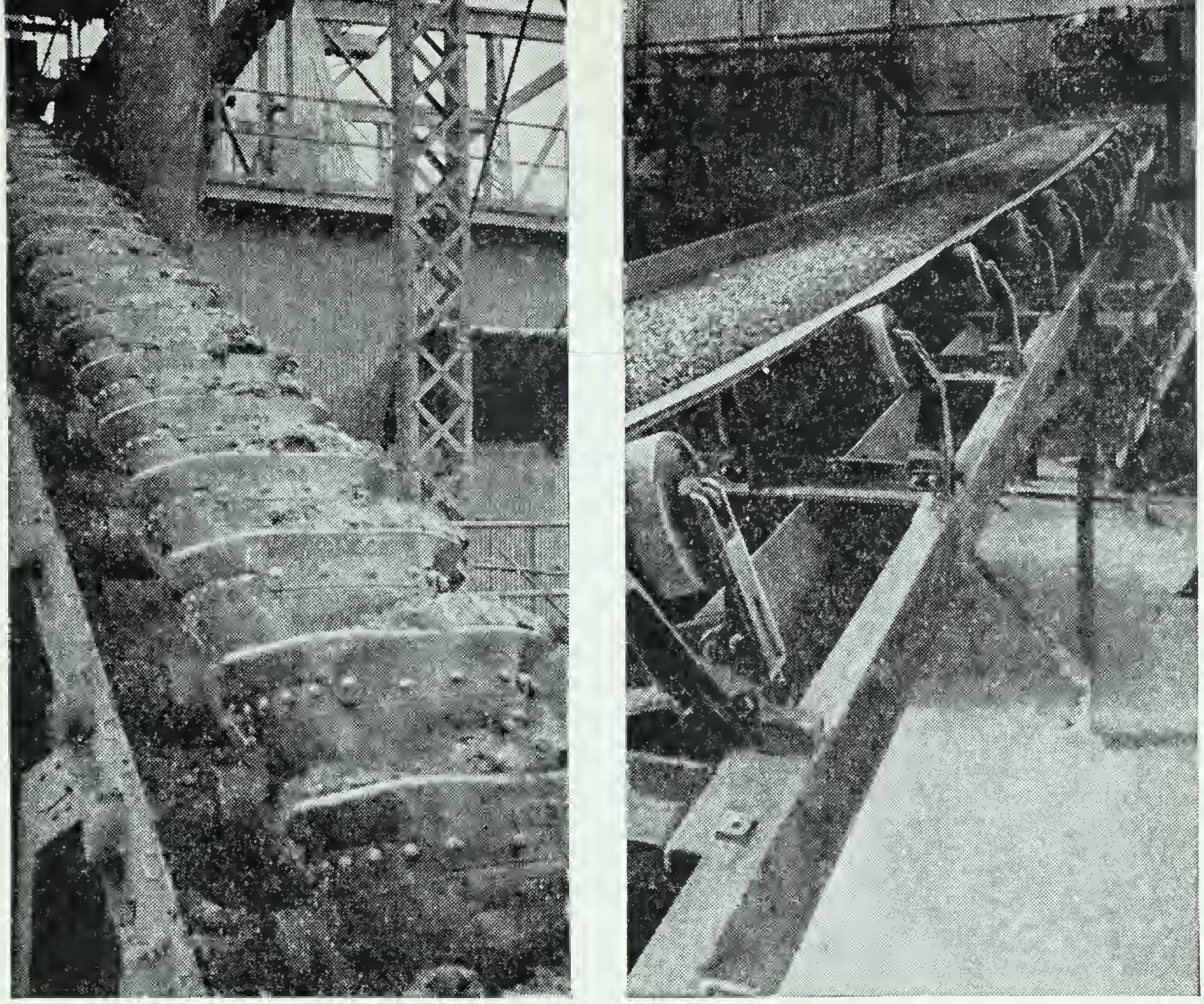
What to do: Set up the rotator and the centrifuge, with muddy water in the tubes. Operate the machine, and observe why the machine increases the speed of rotation.

What was observed: Does the machine gain speed or force? What effect has centrifugal force upon the position of the bottle holders?

What was learned: What is the principle of the milk tester?

Exercise. *Complete the following sentences:* A tractor pulls with a force of 1500 pounds upon a set of plows at the rate of 440 feet a minute. The horsepower is —1—. Another tractor pulls with a force of 660 pounds while moving at the rate of 12 miles per hour. Its horsepower is —2—. Most cultivators are —3— when classified as simple machines. The force which causes spray to flow from the tank comes from a —4—. The milk separator and the tester depend upon —5— force for their operation. The —6— liquid flows to the outside when whirled. The milking machine is operated by reduced —7—. Power is the production of work in definite units of —8—. The unit of measuring work is the —9—.

Science activity. Select for study some machine used in agriculture not explained in this problem. The ensilage cutter, the binder, the apple washer and polisher, the farm water system, the cotton picker, or the grain cleaner are suggested.



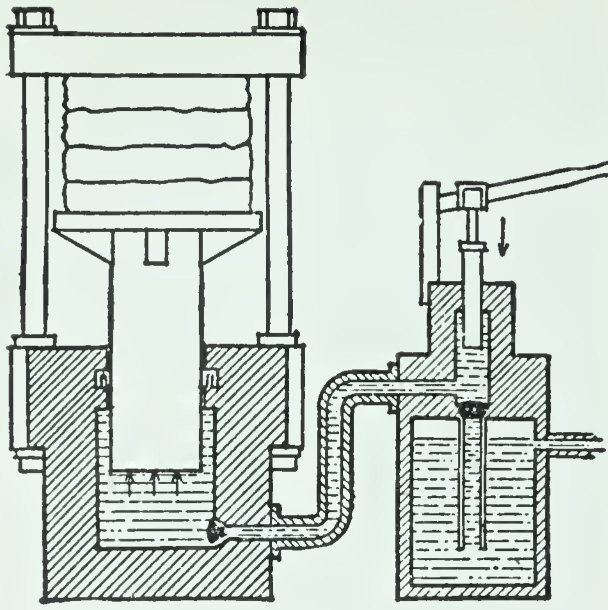
Courtesy American Manganese Steel Co. and Link-Belt Co.

These two conveyers are of the belt type. The buckets are used on a dredge system, the belt to handle ore in a smelter. Note the use of rollers to reduce friction and to keep the belt in line.

8. What are some machines used in industry?

We cannot hope, perhaps, to understand many of the machines used in modern industry. There are many industries, such as textiles and shoes, oil, metalworking, printing, flour milling, lumber manufacturing, and food processing, which use highly specialized machines. Each of these machines requires hours of study for understanding the principles upon which they operate. But there are many machines so widely used in industry that it is profitable for most people to know something about them.

What are conveyers? A conveyer is a machine used for carrying materials from one place to another. Most conveyers consist of belts or chains which pass over pulleys driven by steam or electric motors. Some materials, such as coal, ore, sand, and wood chips used in paper-making, may be carried directly on the belt. Other materials require special equipment to hold them on the belt. Wet or finely divided materials, such as mud or flour, are frequently carried in metal buckets on the chain or belt.



The hydraulic press consists of a force pump to exert pressure on a fluid and of a piston upon which the fluid exerts pressure. Study the diagram to locate the parts.

Another type of conveyer consists of wooden or metal rollers. If an incline is sufficiently steep, boxes, packages, and large articles move down these roller conveyers because of the force of gravity. If the conveyer is level or inclined upward, the rollers are driven by belts or gears to move the articles along against the force of gravity. Lumber, packages, and other large objects are transferred from one place to another in this manner.

A third type of conveyer consists of an overhead track, like a small railroad, on which cars are driven by electric or gasoline motors. Below the cars are chains suspended from pulleys. These pulley systems lift heavy loads from the floor, and the cars carry them to new positions. This type of conveyer is used in factories for transporting heavy machines, such as locomotives and trucks, and in moving heavy ladles of melted steel. A single track and wheel is used in packing plants to move the carcasses of beef and pork.

The work done by a conveyer results from overcoming the resistance of friction or the resistance of gravity.

How do cranes and power shovels work? A crane consists of a long, third-class lever at the end of which is suspended a pulley system. The crane is used to lift heavy loads and move them. In unloading coal from a barge, a crane may be used. The long arm of the crane swings over the barge; the bucket drops down and scoops up its load of coal; the coal is lifted by the block and tackle; the crane arm swings over a railroad car; and the coal is dropped into the car. The steel cable which lifts the coal is wound and unwound on a metal cylinder called a drum. This drum is an axle of a wheel and axle.

Cranes are used extensively in loading and unloading

ships. They are useful in laying steel rails and pipes. They are employed in lumbering to load logs on trains. Electromagnets attached to the cables of cranes are used in moving iron bars and scrap metal.

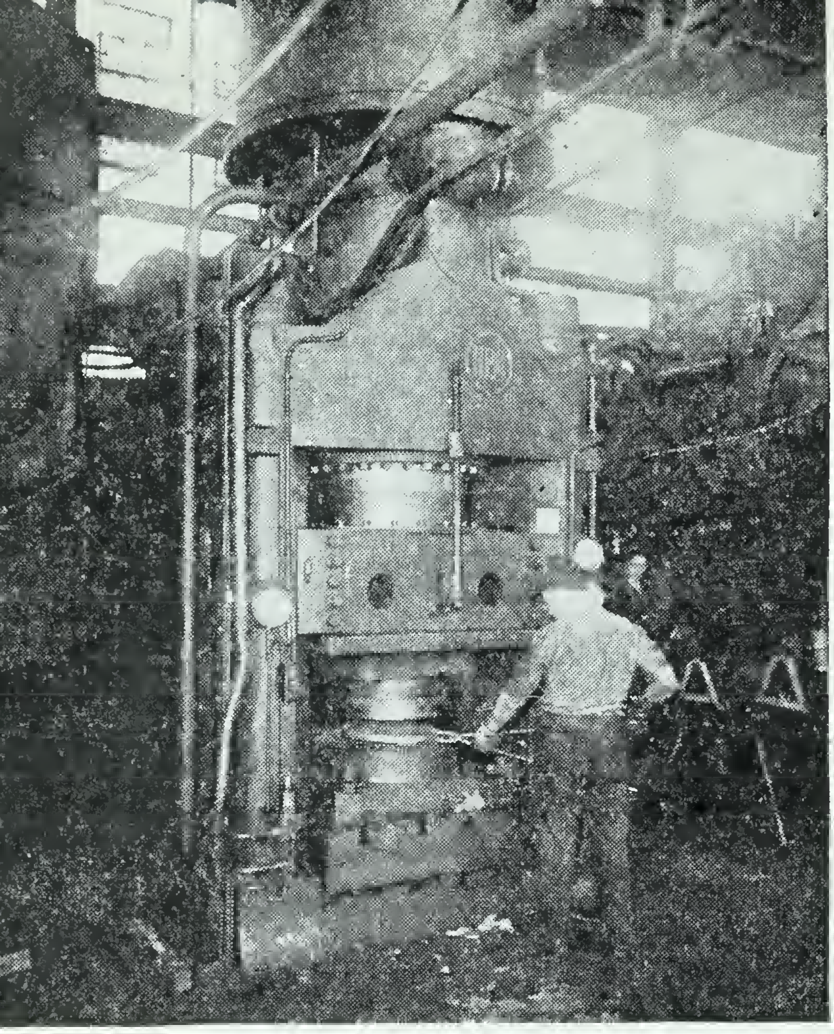
The power shovel is exactly the same in principle as a crane. The shovel is a scoop, on the front edge of which are sharp teeth, which are inclined planes. These teeth loosen soil and rock to make it possible to scoop them into a shovel.

How does the hydraulic press work? The hydraulic press consists of two parts. The first part is an ordinary force pump, which is used to compress a liquid. The second part is a piston and cylinder. The liquid from the force pump is forced into the cylinder and exerts pressure upon the piston. The amount of force exerted by the press equals the area of the piston multiplied by the pressure. That is, a piston with an area of 300 square inches under a pressure of 200 pounds per square inch can exert a total force of 60,000 pounds, or 30 tons.

The pressure on the piston of the force pump is the same as the pressure upon the press piston, because enclosed liquids carry pressure equally in all directions. If the area of the pump piston is 10 square inches and the pump exerts a pressure of 200 pounds per square inch, the total force required is only 2000 pounds, or one ton. The hydraulic press mentioned above would give a mechanical advantage of 30. The easiest way to find the mechanical advantage is to divide the area of the press piston by the area of the pump piston. 300 divided by 10 equals 30.

The most familiar hydraulic press is that used in the barber's chair. The barber operates a pump by pressing on a pedal with his foot. The pump compresses oil which flows into the cylinder to lift the chair. The common automobile grease rack which lifts the automobile high above the ground usually obtains its force from a hydraulic press.

The hydraulic press is used in industry to shape metal. A piece of sheet metal is placed over a pattern called a *die*. The piston forces the metal into the die and shapes it. The cover and tub of your washing machine and the metal top, headlamps, and wheels of your automobile were probably pressed into shape by a hydraulic press. A hydraulic



Courtesy The Hydraulic Press Mfg. Co.

The hydraulic press is used to shape metal. Note the huge piston above the piece of metal. Why is the metal handled with tongs?

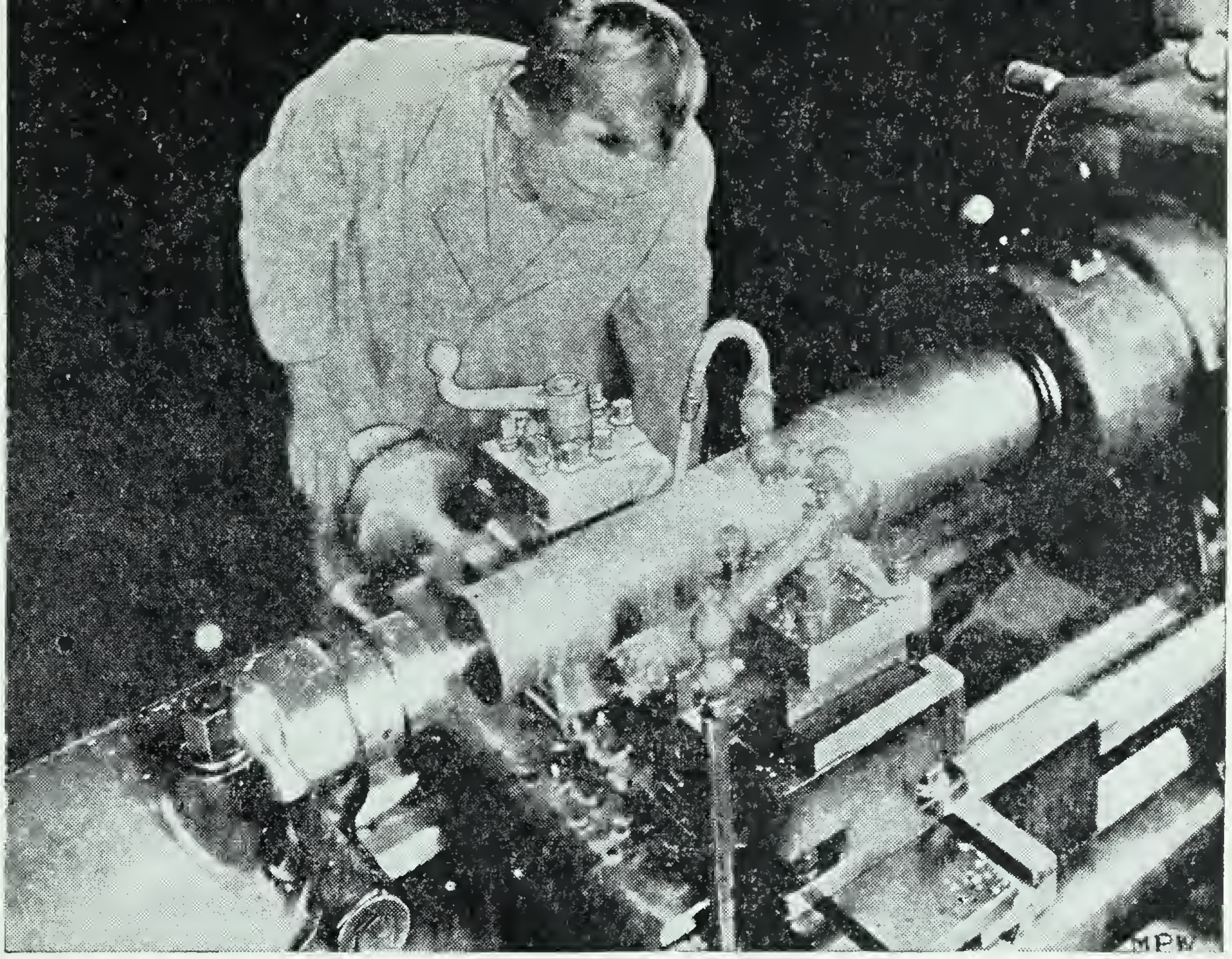
press, producing a total force of 5000 tons, is used in shaping the metal parts of the huge flying boats used in transoceanic airplane service. The parts are pressed out separately and welded together to form the completed plane.

Cotton is baled by a small hydraulic press. Oil is pressed from the seeds of flax, peanuts, and cotton by hydraulic presses. These machines mold plastic materials into vanity cases, doorknobs, light sockets, and umbrella handles. They press salt into blocks, and are used in making dry ice.

What is a lathe? A lathe is one of the most essential of all industrial machines. It is really a wheel and axle. The axle is a piece of wood or metal which is attached by clamping devices to the wheels, one at each end, to hold it steady. When the wheels are rotated by power from a motor, the piece of wood or metal is turned.

To use the lathe, a cutting tool is held against the piece of turning wood. The rough stick soon becomes rounded. By moving the cutting tool to cut deeper or less deeply into the wood, beautifully curved designs are produced. The legs of furniture, such as chairs, tables, and pianos, are turned on lathes.

The metal lathe is even more important than the wood lathe. The operation is similar, except that the lathe is much stronger, it turns more slowly, and the cutting tools are held by the machine instead of by the operator. Without the lathe it would be impossible to produce the many accurately fitted parts used in modern engines, pumps, and presses. Pistons, fittings, and many other machine parts are cut entirely on lathes.



Courtesy The American Tool Works Company

This lathe is used to cut metal. Note the stream of oil flowing over the metal to cool it. The operator controls the cutting tool.

How are grinding machines used? There are many jobs which depend upon grinding to make tools fit accurately. One of the important grinders is used to fit inside a cylinder, where it is rotated to polish and cut to size the inside of the cylinder. The modern gasoline engine would be impossible without accurately fitting pistons and cylinders.

Grinders are used to polish many metal parts. When automobile bodies are welded, the rough spots are smoothed by grinding. All sharp tools, razor blades, axes, knives, and scissors are ground to produce an accurate edge.

DEMONSTRATION. HOW DOES THE HYDRAULIC PRESS WORK?

What to use: Model hydraulic press, glass jar.

What to do: Operate the hydraulic press. Count the strokes of the pump needed to lift the piston. Measure the diameters of the two pistons and calculate the mechanical advantage. Observe the operation of the valves.

What was observed: How does the press work? How do the valves move on the upstroke? The downstroke?

What was learned: State the principle of the press and the method of figuring its mechanical advantage.

Exercise. *Complete the following sentences:* When a conveyer lifts a load, it overcomes —1—. When a load is moved on the level, a conveyer overcomes —2—. The load of a crane is lifted by a machine called a —3—. The mechanical advantage of a hydraulic press is proportional to the —4— of the —5—. A press with a piston area of 240 square inches and a pump piston area of 12 square inches has a mechanical advantage of —6— and, with a force of 500 pounds, would press with a force of —7— pounds. Enclosed liquids exert —8— equally in all —9—. The lathe is a —10—. Grinders apply their force to overcome —11—.

Science activities. 1) Visit a factory, and observe as many machines as you can.

2) Make a model crane with a mechanical toy building set, and work out its mechanical advantage.

3) Make a report on materials used in grinding wheels. Look up carborundum, sandpapers, emery, and pumice.

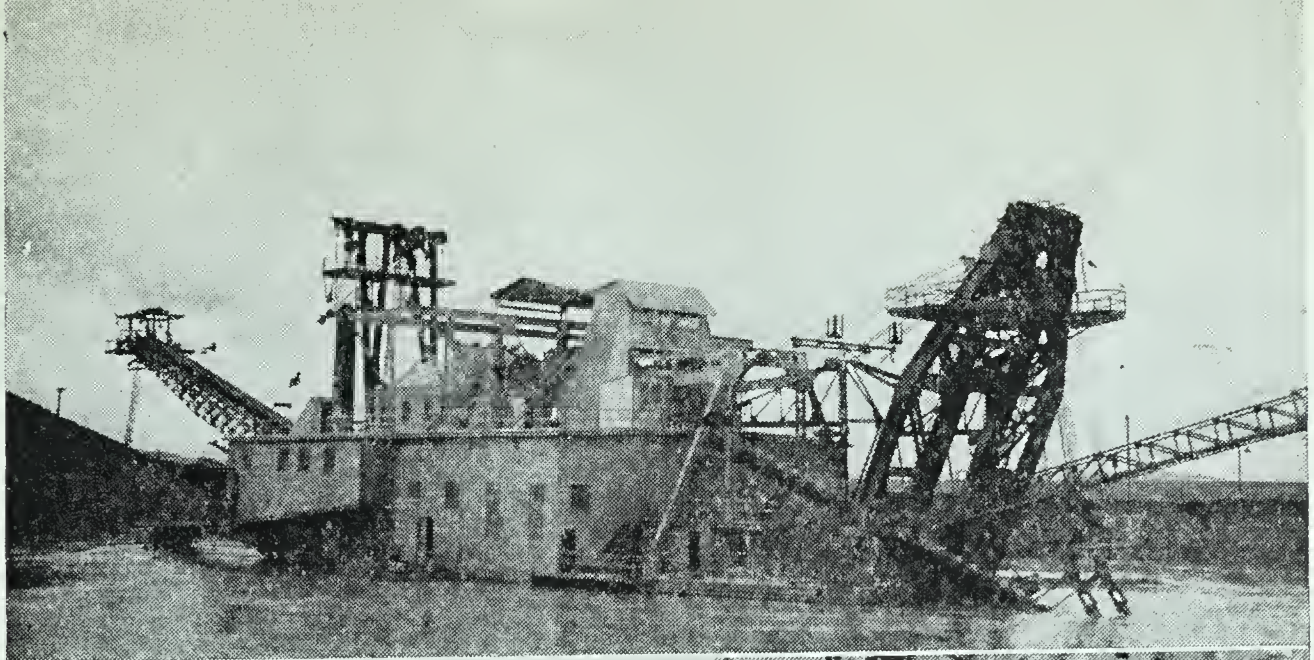
9. What happens to the energy used in doing work?

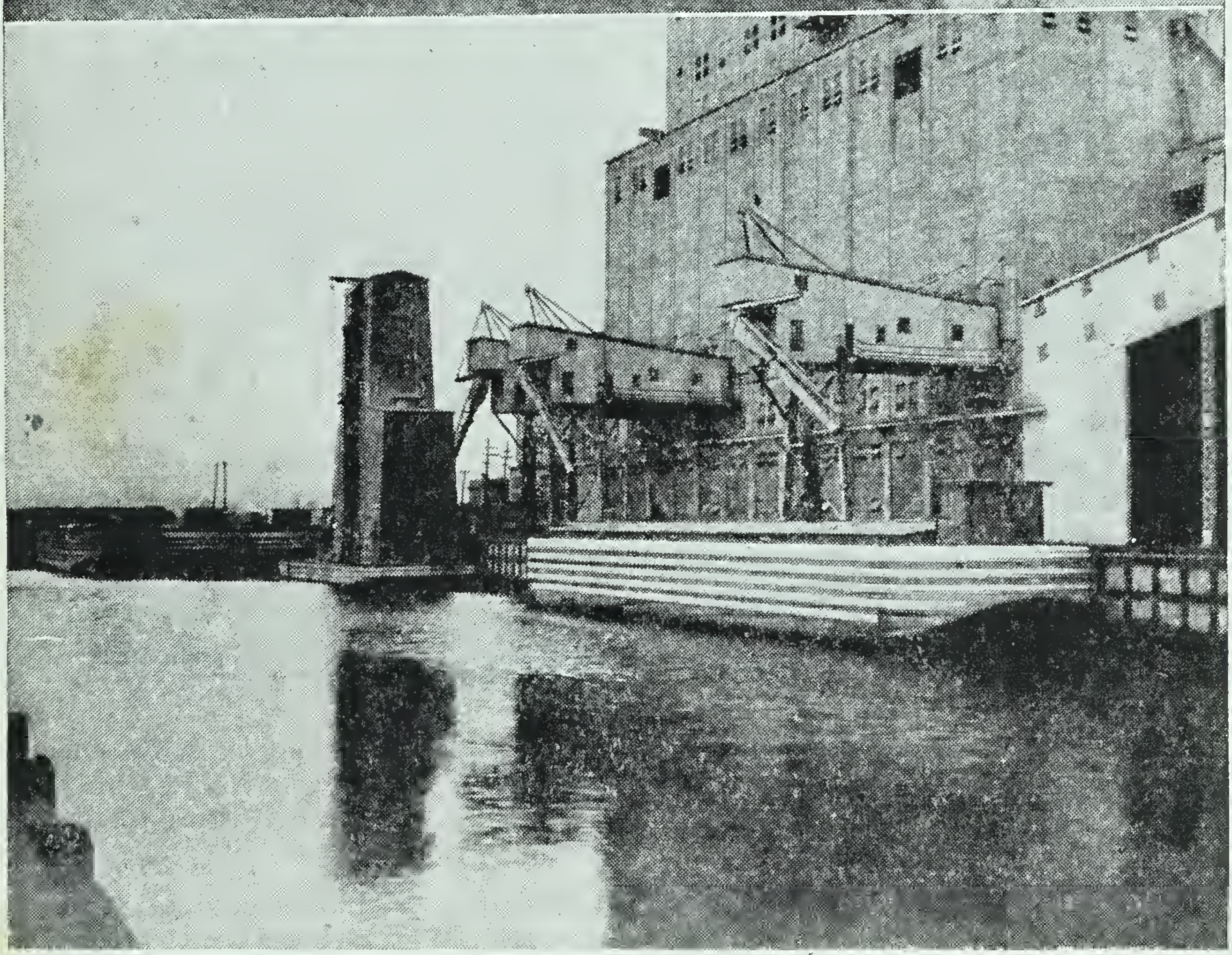
As you already know, energy cannot be created or destroyed. Yet when we do work, it seems that the energy which we use has disappeared completely. What happens to it?

Do moving objects have energy? An object at rest resists being put into motion—that is, it has inertia. When energy is put into the object sufficient to start it moving, the energy is carried along in the object. The energy possessed by a moving object is called *kinetic energy.*

All objects on which work is done have kinetic energy, for work is defined as a force acting through a distance. If the object in motion encounters no resistance after it starts moving, it will continue indefinitely to move, with the same amount of energy present that it had when it started. On the earth it is completely impossible to move an object in such a way that it will encounter no resistance. The only possible situation in which an object could move in this manner would be in outer space, where there is no air, no light, and no gravitation of other bodies.

Can energy be stored? When a moving object encounters the resistance of gravity, it gradually is pulled toward the earth. If we let the object fall freely, it comes to rest on



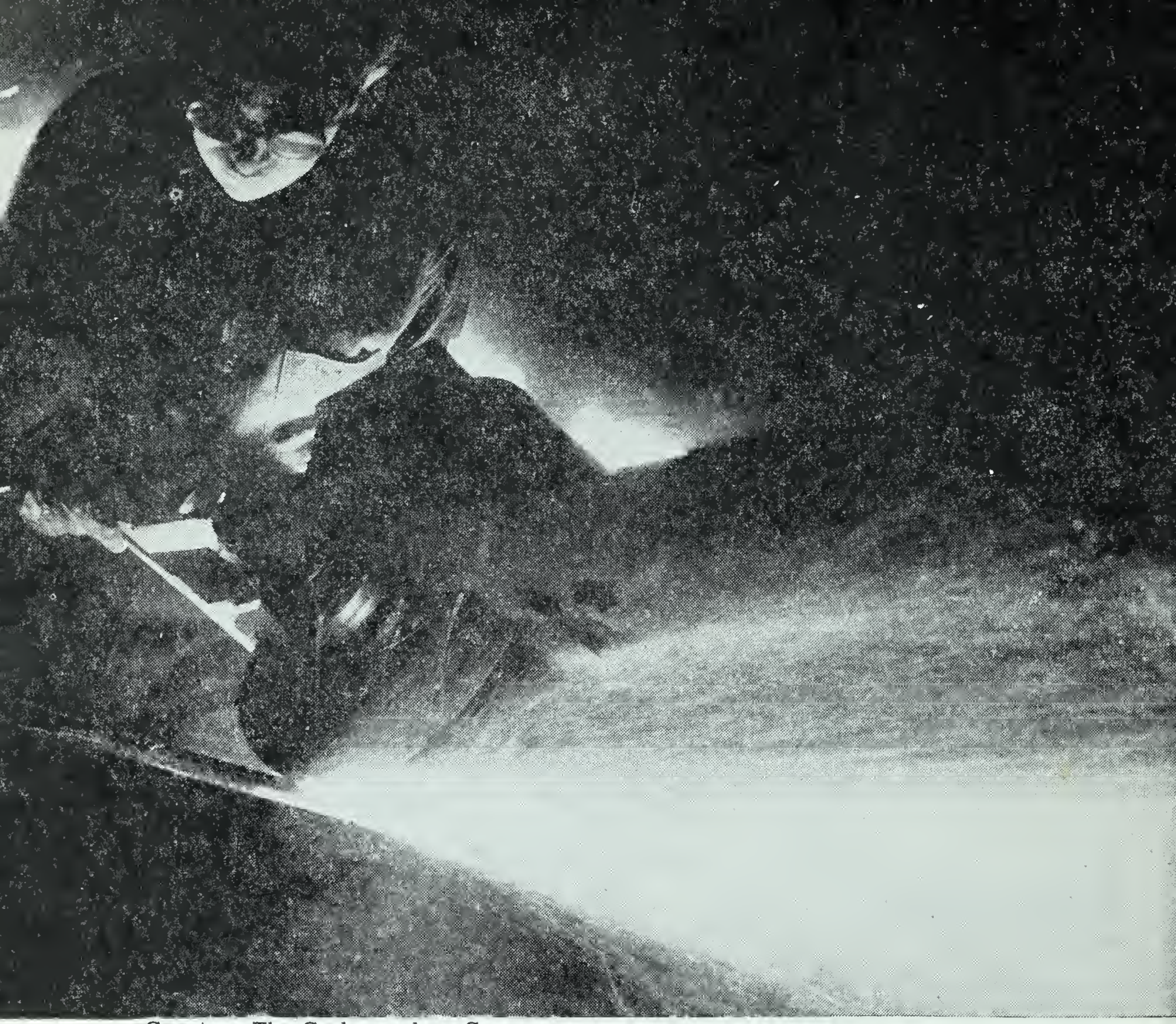


Courtesy American Manganese Steel Co. and Dravo Corporation

When gravity is overcome to do work, energy is stored. The energy stored in the pile of mud, shown at the left in the top picture, is useless, but the energy in the grain in the elevators below will cause it to flow into the barges.

some supporting surface which it encounters—the ground, a floor, or a table top. If an object is lifted to a height and brought to rest on a support, the energy which it has may be stored up for future use. Such stored energy is called *potential energy.*

If we pump water into a high tank, the water remains in the tank, exerting pressure in proportion to the height to



Courtesy The Carborundum Company

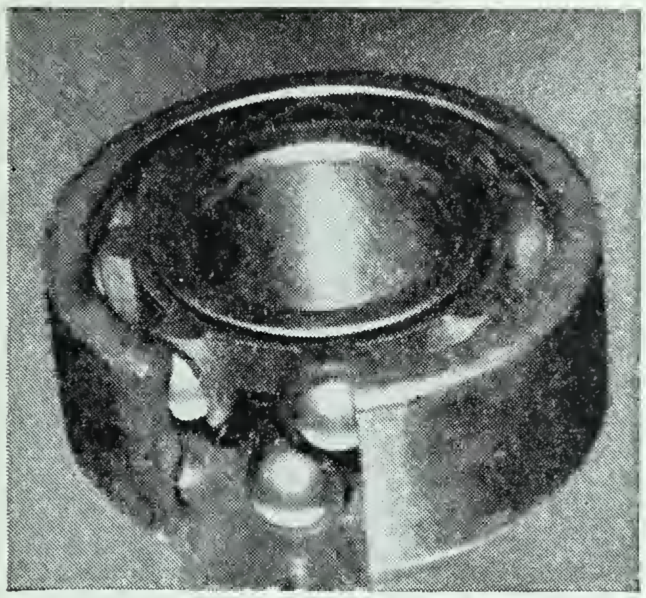
Friction produces heat. This grinding wheel throws off a shower of sparks as it cuts into metal.

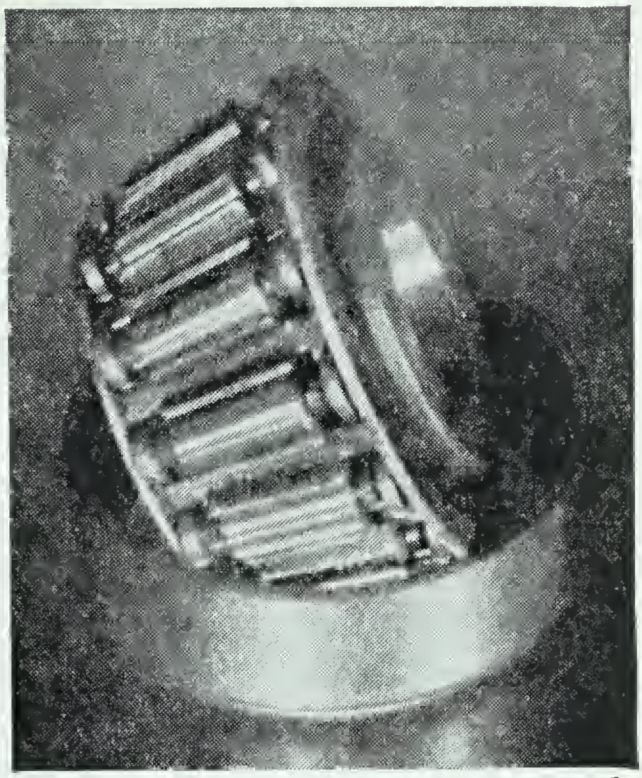
which it is lifted. Water at a height of 100 feet exerts a pressure of about 43 pounds per square inch at the ground, if it is carried to the ground by a pipe.

If we run the water through the pipe into a turbine, we can make the turbine do work, using the energy stored in the water in the tank.

One of our most important sources of energy is the potential energy of water stored in the atmosphere, in mountain streams, and behind high dams. The kinetic energy which is thus stored comes from the heat of the sun, which evaporates water.

Can mechanical energy be changed to heat energy? When a cold grinding machine turns against a cold piece of metal,





The ball bearings (*above*) reduce friction. Part of the metal ring has been cut away to show the bearings. The tapered roller bearings (*right*) have been removed from the metal ring into which they fit.

hot sparks fly into the air. The heat comes from the energy of the moving wheel. Friction causes mechanical energy to produce heat. The heat is radiated into space and lost. If the grinding continues for some time, the wheel and metal may become hot enough that the metal glows. Then we can see light and feel infrared radiation.

The spectacular sparks given off in grinding metals make it possible for us to see the heat loss usually not noticed. All friction produces heat. When a stone falls to the ground or when a drop of rain falls to the earth, its kinetic energy is changed to heat. The net result of most work is to change energy to heat, for it is only rarely that we store as potential energy even a small fraction of the kinetic energy held in the moving object.

An interesting experiment can be done to measure roughly the amount of heat produced in doing work. A cardboard tube three feet long is closed with corks at each end. In the tube two ounces of shot are placed. Then the tube is turned over, end for end, and the shot allowed to drop the length of the tube. With each eight turns, three foot-pounds of work are done. The shot is then poured into water. If water, shot, and tube are at room temperature at the beginning of the experiment, any increase in the temperature of the water is

caused by the changing of mechanical energy into heat.

What is efficiency? In every machine there is much waste of energy. Not only is there friction, but there is loss of energy caused by moving the parts of the machine. That is, when we lift sand on a shovel, we lift not only the sand but also the shovel. All the effort used in lifting the shovel is wasted.

We can measure the useful work done, and we can measure the total work used to produce the useful work. Efficiency is defined thus: $\text{Efficiency} = \dfrac{\text{Useful work}}{\text{Total work}}$

For example, suppose that 240 pounds of bricks in a box are being lifted with a block and tackle to a distance of 10 feet. The box weighs 40 pounds. Then there is friction in the pulleys and in the blocks where the ropes drag. The total amount of work done to lift the bricks is 3200 foot-pounds.

The efficiency of the system is: $\dfrac{240 \times 10}{3200} = .75$

The highest possible theoretical efficiency is 100 per cent, but no machine can possibly be that efficient.

How is efficiency increased? There are several ways in which efficiency is increased. One way is to reduce friction. Oil and smooth surfaces reduce the friction of many common machines, such as the sewing machine, the washing machine, and the gasoline engine. Use of rolling instead of sliding friction increases efficiency. The wheel makes a toy wagon more efficient than a sled drawn along a concrete walk. Ball bearings are used in roller skates and bicycle wheels to reduce friction. Trains, trucks, and heavy machines use roller bearings to reduce friction.

A second way of increasing efficiency is to reduce the weight of the moving parts of the machine. If a light machine will do the work as well as a heavy machine, it is cheaper to use the lighter machine. Heavy machines have greater weight and more inertia to overcome.

A third way to increase efficiency is to keep moving parts in motion. Every time a part of a machine stops, its kinetic energy is changed to heat by friction and is lost. Rotating motion is less wasteful of energy than back-and-forth motion.

This fact explains in part why turbines are more efficient than other engines.

DEMONSTRATION. HOW DO WE MEASURE EFFICIENCY?

What to use: Board, brick, spring balance, cord, ruler.

What to do: Set up the board as an inclined plane. With the spring balance, drag the brick up the board, noting the amount of force needed. Measure the length and height of the plane.

What was observed: Calculate the total amount of work done by multiplying the force used on the balance times the length of the plane. Find the useful work by multiplying the height of the plane by the weight of the brick.

What was learned: Calculate efficiency. What was it?

Exercise. *Complete the following sentences:* A moving object has —1— energy. An object at rest may have —2— energy because of its position. Energy that is not stored as potential energy is changed to —3— by —4—. Energy, although not —5—, is lost into space completely by the process of —6—. Efficiency equals —7— divided by —8—. Friction may be reduced by use of —9— on smooth surfaces or by use of —10— friction. Heavy machine parts are wasteful because of the resistance of —11— to lifting weights.

Science activities. 1) Make a study of bearings. Collect as many as you can from old machines.

2) Report on perpetual motion machines.

A Review of the Unit

A machine is a device for applying force advantageously. Mechanical advantage is the number of times a machine multiplies the force put into it. Simple machines are the three classes of levers, inclined planes, the pulley, the wheel and axle, the wedge, and the screw. Work is done when force acts through a distance. Energy used in doing work is changed to heat by friction or is stored as potential energy. A moving object has kinetic energy.

Force is applied to pistons or to revolving blades. Centrifugal force is the tendency of rotating objects to move in straight lines. All complex machines are made up of simple machines and working surfaces.

Power is the production of work in definite units of time.

An exercise in thinking

Match the principles and related ideas, according to the directions given in the review at the end of Unit I.

List of principles

A. Work is a force acting through a distance.
B. Force times distance equals resistance times distance.
C. Kinetic energy is the energy of a body in motion.
D. Potential energy is the energy possessed by an object because of its position.
E. One form of energy may be transformed into another form of energy.
F. Useful work divided by total work equals efficiency.
G. When pressures upon opposite sides of an object are unequal, the object tends to move toward the lower pressure.
H. Inertia is the tendency of an object at rest to remain at rest, or of an object in motion to remain in motion in the same straight line.
I. Power is the production of work in definite units of time.

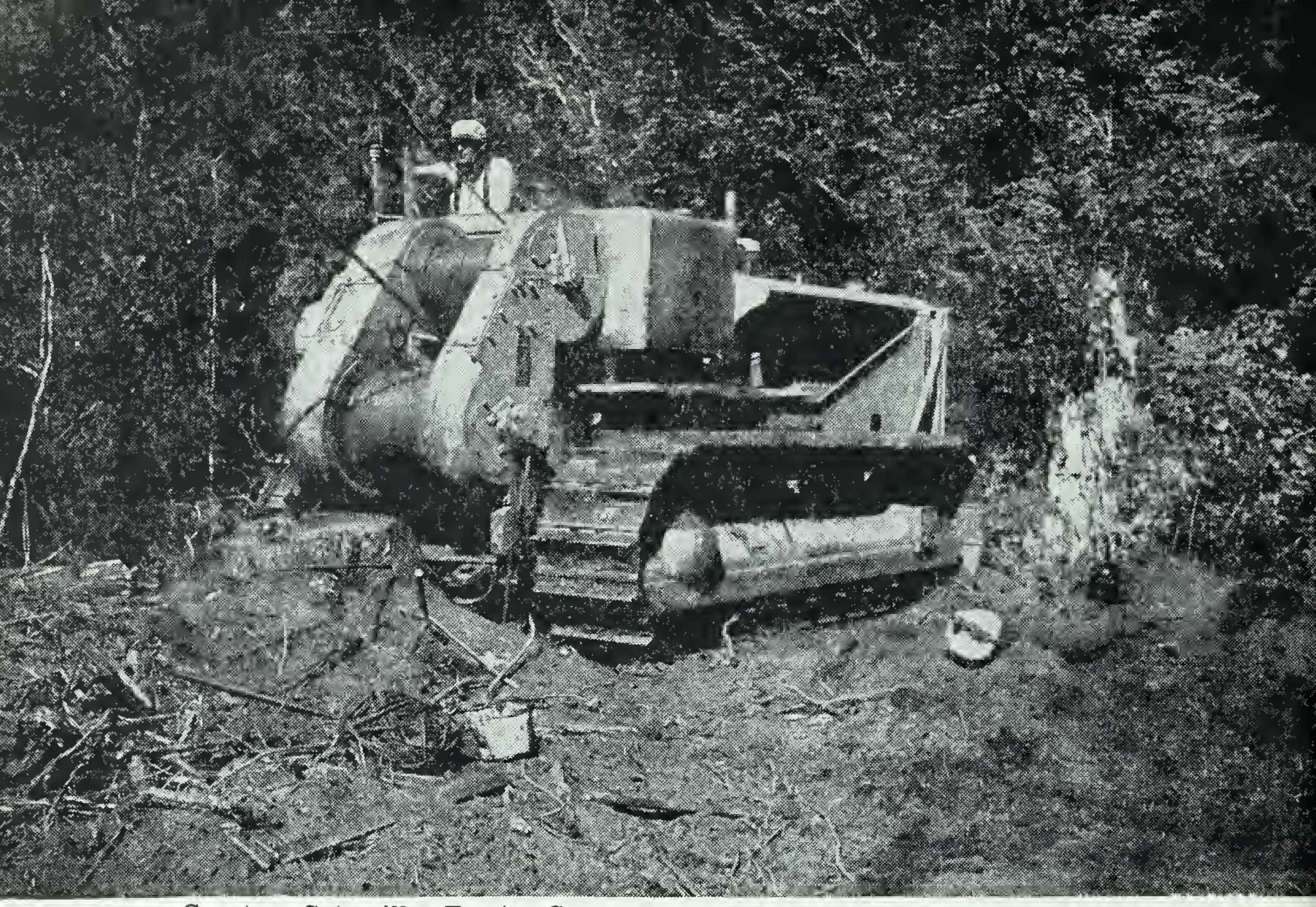
List of related ideas

1. The unit of measuring work is the foot-pound.
2. With one movable pulley, it is necessary to pull two feet of rope for each foot the load is lifted.
3. A brick on a wall contains energy.
4. A nail becomes hot when driven into a board.
5. Rotating objects tend to fly out in straight lines.
6. Steam engines waste 90 per cent of their energy.
7. A swinging hammer delivers a heavy blow.
8. Cream is separated by centrifugal separators.
9. 33,000 foot-pounds of work per minute are one horsepower.
10. A ball thrown through the air gradually loses force.
11. A pump valve is opened and closed by the flow of water.
12. We do no work unless an object is moved.
13. Steam exerts force upon the piston of an engine.
14. Use of oil on a machine increases its efficiency.
15. The faster an object moves, the harder it hits an obstacle.
16. Water behind a dam has energy stored in it.
17. A machine with whirling blades may be more efficient than a machine with a back-and-forth motion.
18. If a string tied to a weight is jerked, it breaks.
19. Heat is used in engines to do work.

20. Farmers use tractors to get work done in time to save crops.
21. Mechanical advantage is the number of times a machine multiplies the force put into it.
22. Automobiles skid in turning corners rapidly.
23. Distance on a lever is measured from the fulcrum.
24. The pressure of water is in proportion to its depth.
25. A machine that increases the speed decreases the force.
26. A single fixed pulley gives a mechanical advantage of one.
27. Expanding gases in an engine provide force to do work.
28. The mechanical advantage of a hydraulic press is in proportion to the area of the pistons.
29. Energy is stored between strokes of an engine in the flywheel.
30. Molecules of steam take up about 1700 times as much space as do the same molecules of water, because they nave more energy.
31. One horsepower equals 746 watts of electrical energy.
32. Running water can do work.
33. Much work is done in lifting loads against gravity.
34. A power machine can do work in less time than a man can.
35. Simple machines usually waste less energy than do complex machines.
36. The work done by use of an inclined plane equals the height of the plane times the weight of the load.
37. The mechanical advantage of an inclined plane equals length divided by height.
38. Wind exerts force upon the front of a windmill vane.
39. Roller bearings in train wheels reduce friction and loss of energy.
40. A bent bow has energy stored in it.

Some things to explain

1. Describe the changes which take place in iron from the ore to the form of an automobile fender. List the machines used in the work.
2. List 20 simple machines used in the home, and explain how they are used.
3. Why do we say that machines cannot save work?
4. How many simple machines are there in a pencil sharpener? Name them.
5. How many horsepower are produced by a generator which produces 150,000 kilowatts?



Courtesy Caterpillar Tractor Co.

This man sitting at the controls of a hoisting machine is moving huge logs into piles. How much effort would a primitive man have had to put forth to accomplish the same results?

6. Show how the sun is the source of energy in a steam engine.
7. Which of the six simple machines do you see used most? Why?
8. What advantage does a turbine have over an ordinary steam engine?
9. Why is the large sprocket of a bicycle in front?

Some good books to read

Bock, E., *What Makes the Wheels Go Around*
The Book of Knowledge
The Book of Popular Science, Grolier Society
Collins, A. F., *The Experimental Mechanic*
Collins, A. F., *The New World of Science*
Compton's Pictured Encyclopedia
Fisher, Elizabeth, *Resources and Industries of the United States*
Gibson, C. R., *Machines and How They Work*
Meister, M., *Energy and Power*
Reck, F. M., *Automobiles From Start to Finish*

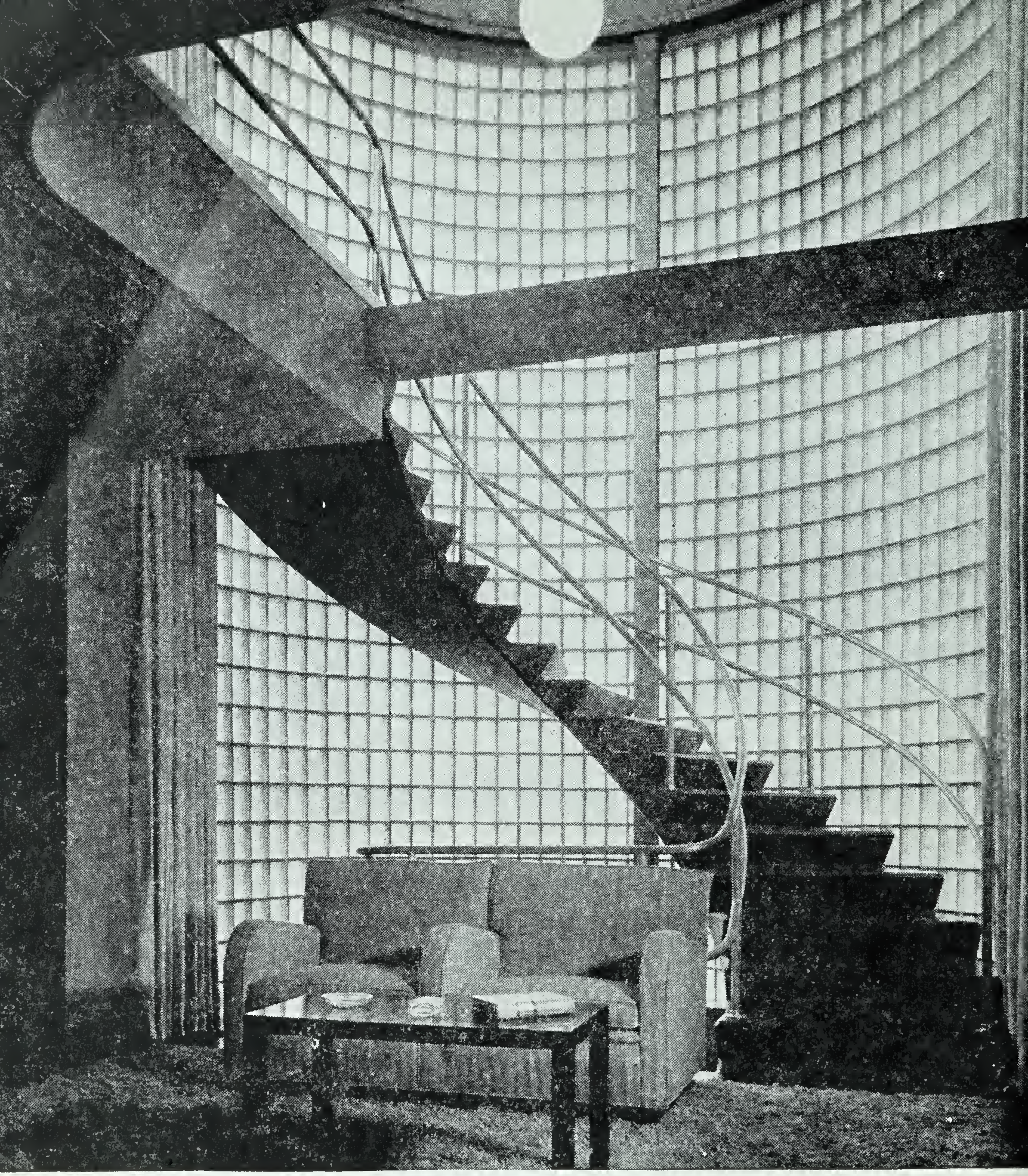
Reed, Brian, *Railway Engines of the World*
Salt, Harriet, *Mighty Engineering Feats*
Verrill, A. H., *Gasoline Engine Book for Boys*
Williams, H. S., *The Story of Modern Science*
World Book Encyclopedia

Some interesting motion pictures

Energy and Its Transformations. Erpi (*16 sound*)
Men and Machines. Audio Productions (*16 sound*)
Energy and Work. De Vry (*16 silent*)
Simple Machines. Eastman (*16 silent*)
Power. (2 reels). U. S. Bureau of Mines (*16 silent*)
Compressed Air. Eastman (*16 silent*)
Water Power. Eastman (*16 silent*)
Steam Power. Eastman (*16 silent*)
Power Within. (3 reels). U. S. Bureau of Mines (*16 silent*)
Where Mileage Begins. Y.M.C.A. Motion Picture Bureau (*16 sound*)
Four Stroke Cycle Gas Engine. Eastman (*16 silent*)
Modern Trend in Turbine Design. (2 reels). General Electric Company (*16 sound*)
Diesel Engines. International Harvester Company (*16 sound*)

Some related lantern slides

Machinery. Keystone View Co.



Courtesy Owens-Illinois Glass Company

UNIT EIGHT

HOW CAN SCIENCE HELP TO PRODUCE BETTER HOUSES?

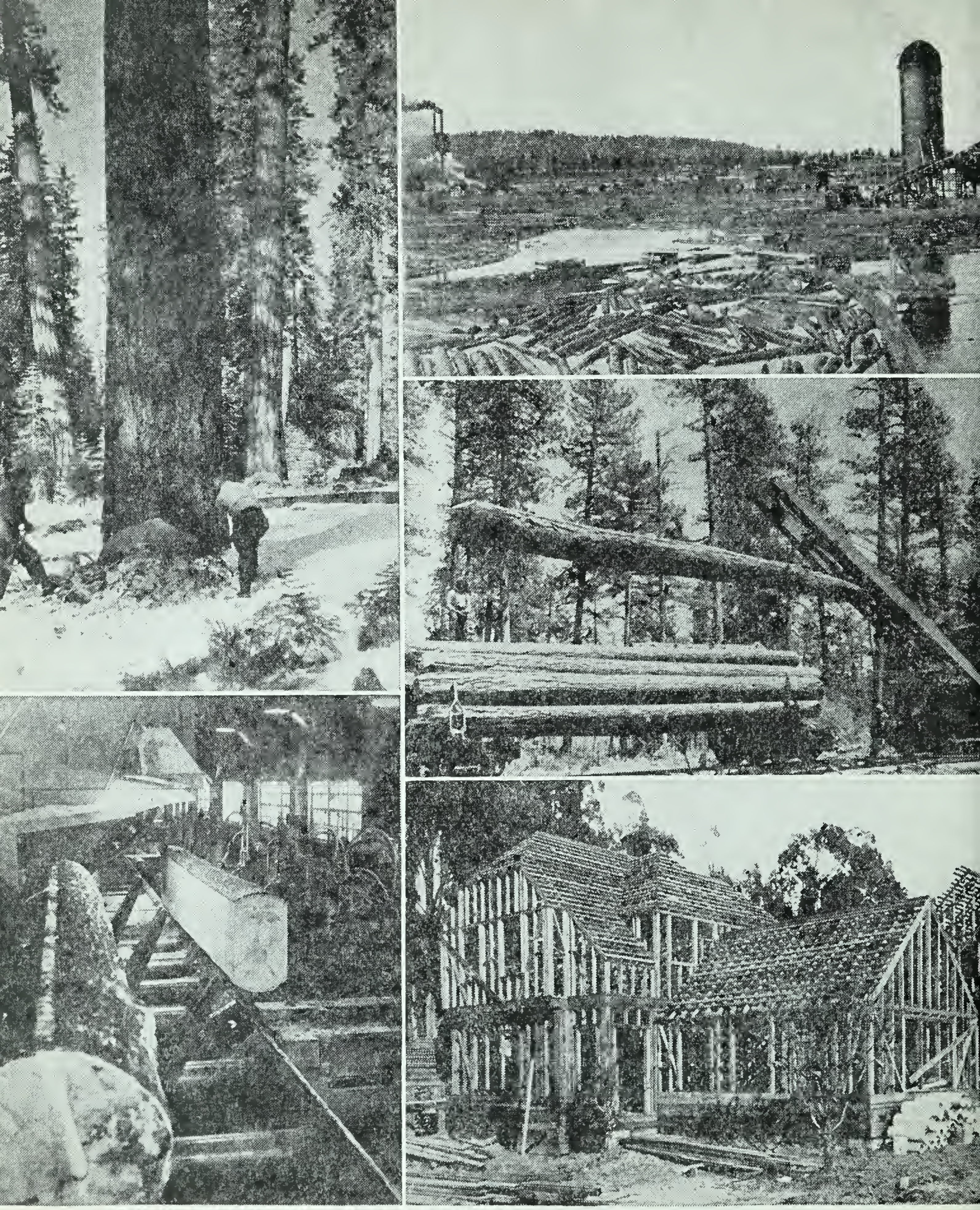
BEFORE we build a house, we must produce a design for using space to meet human needs. A design for a house is really based upon a design for living. Since people today have more leisure than their ancestors did, the house designed for modern life has space provided for recreational living. Many people have automobiles, and in their houses the garage will become not only part of the house but may become the main entrance to the house. The modern woman does less cooking than her grandmother did and has more machines to work with. Thus the modern kitchen will be a small, attractive, and efficient machine shop. From these examples it is evident that a house designed for another age cannot meet present-day needs.

The design of the house must be developed in terms of the best structure available, and the house must be made of materials best fitted to the design. The roof may be flat to provide an added area for living, or it may be sloping if it is intended only to shed water. The materials used may be brick, stucco, glass block, stone, steel, chromium, plywood, plastics, or wood. The choice depends upon how well they contribute to making the house perform the functions for which it is designed, as well as upon taste, cost, and custom.

When a design is complete, plans are drawn and specifications of materials are made to direct the builder in producing the house which meets our needs.

The house designed for living is called a functional house. The functional house is built to recognize scientific principles of lighting, heating, insulation, safety, labor saving, sanitation, convenience, and construction. The houses in which most of us live are hopelessly inefficient when judged by present standards.

Before many of us are ready to live in and enjoy a truly functional house, we must change our ideas of what to expect from a house. For most of us are too easily satisfied with houses that are not as nearly perfect as they should be. A boy who has never driven a horse hitched to a buggy still has to help with the storm windows. Girls still help to clean houses that are dirty merely because they are poorly made. Before we can build a modern house, we must know what one is like.



Courtesy Western White Pine Association

The trees which are felled in the forest (*top left*) are cut into logs and loaded on trains (*center right*). At the sawmill (*top right*) the logs float in a pond until needed. Boards are then sawed from the log (*bottom left*) which is moved past the saw on a complex carriage, and the finished lumber is used in building houses, such as the one shown at the bottom.

1. What plant products are used in housing?

Plant products have always been used in building houses. Primitive man used sticks and leaves. Modern man uses lumber, plywood, pressed wood, insulation, paper, cloth, and paints and varnishes.

What is lumber? Lumber is the best material for building inexpensive houses and is extensively used in most houses. It is cheap, widely available, easily worked, and accepted by most people as the standard building material. It is not particularly durable, however, and warps and shrinks in changing weather. It leaks air through the pores and cracks. Lumber burns readily.

More lumber is made from pine trees than from any other kind, with Douglas fir second. These two softwoods provide three-fourths of our lumber. The commonest hardwood is oak, which accounts for 6 per cent of our lumber. Cypress, redwood, and cedar are desirable woods for resisting weather. Most of the other woods are used in small amounts for trim, flooring, and furniture.

The trees are cut into logs in the forest and stacked and dried. The logs are transported to the mill by truck, train, or by floating in a stream. The log is soaked in the mill pond until stones and bark are loosened. Then it is sawed into rough boards by a circular saw or a band saw. The rough, wet, splintery boards are dried. When sufficiently dry, the boards are planed and trimmed to the desired size.

How is plywood made? To make plywood, a thin layer of wood is peeled from the log by a knife held against the log as it is rotated in a lathe. Three or more layers of thin wood, called veneer, are glued together. The grain of one layer runs at right angles to the grain of the veneer next to it.

The glued plywood is stacked in a hydraulic press and forced together under a pressure of 200 pounds per square inch. After six hours the glue is set. The surface of the plywood is finished by sanding machines. The smooth plywood is easily worked, has interesting grain, and is amazingly strong. A waterproof plywood is available.

The grain of boards and plywood depends upon cutting through the annual rings of growth in such a way that the

edges of the cut rings show in patterns. If the rings are cut to show the edges, the boards are said to be quarter-sawed. If the rings are cut at an angle of less than 45 degrees, the grain is slash grain. Most plywood shows a very wide slash grain.

How are fiberboards made? Fiberboards may be almost as hard as metal or as loose and porous as a quilt. The fibers used may be from sugar cane, flax, or wood. Some are white, some tan, and some brown.

To make fiberboard from wood, the logs are reduced to chips, which are sorted by screens and fed into tanks. Steam is admitted to the tank under pressures reaching 1000 pounds per square inch. Suddenly the bottom of the tank is opened, and the fibers are loosened from each other by the expanding steam. The fibers mixed with water are run on a screen or blanket, and the water is withdrawn by vacuums and by pressure rollers. The fibers mat together. When a sufficient thickness is built up, the boards are pressed. To make a hard, polished board, a board 4 x 12 feet is subjected to a pressure of 1000 tons. Softer boards are subjected to less pressure.

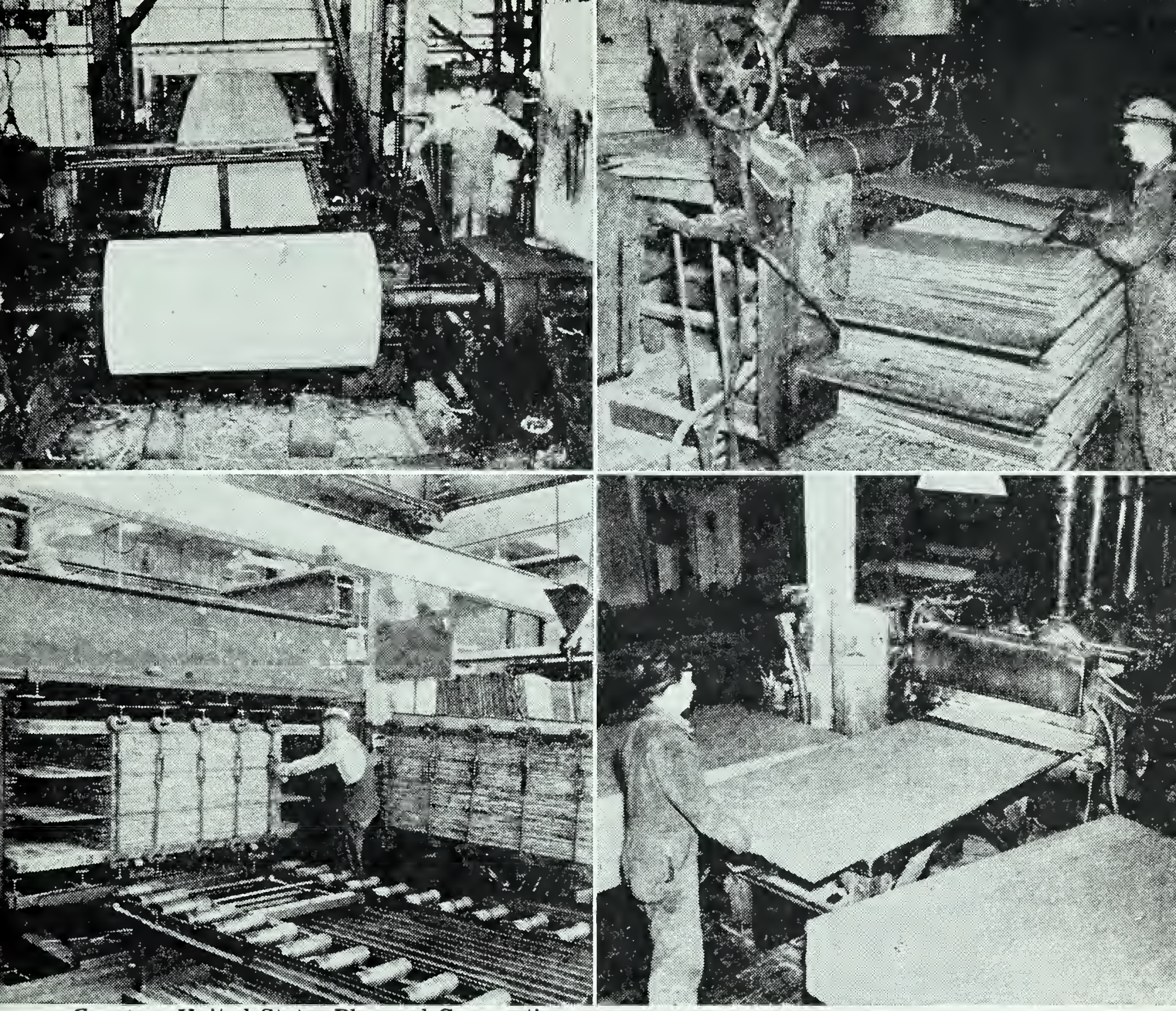
The soft fiberboards are used for insulation and for deadening sound. Hard fiberboards are used for decoration, table tops, walls, and unusual effects.

What other fibers are used in building? Paper is made from fiber by a process similar to making fiberboard. Loose fiber is blown into spaces between walls or formed into quilts between layers of paper.

Some roofing is made from felt, which is made from cloth fibers. The felt is soaked in hot tar and pressed between hot rollers. A hard, waterproof finish is produced. Sometimes gravel is pressed into the surface of roofing, making it more fire-resistant and durable.

How are shingles used? Shingles are sawed from cedar. Cedar is notable for its resistance to weathering and decay. Shingles are used for both roofing and wall covering.

How are paints, varnishes, and oils made? Almost every liquid used to finish wood has a plant origin. Linseed oil is produced by crushing the seeds of the flax plant and filtering the extracted oil. It is usually boiled before use, for the raw



Courtesy United States Plywood Corporation

Reading from top, left to right, these pictures show veneer being cut from a log by a blade held against the rotating log; strips of veneer being glued and (*bottom*) pressed together in a hydraulic press; and finishing the outside surfaces of the plywood by sanding machines.

oil dries slowly. Turpentine is produced from the sap of pine trees. The sap or pitch is distilled to separate the turpentine from the heavier resins. A paint oil recently has been developed from the soybean. Tung oil, pressed from the nut of the tung tree, is another important paint carrier. This tree has recently been introduced into the United States from China. Alcohol is made by distilling fermented sugar from corn, potatoes, or other starchy crops.

Paint is a mixture of linseed oil and turpentine or of soybean oil and tung oil or of combinations of the four oils, in which a ground mineral is in suspension.

Varnish is a resin or gum from a plant dissolved in a

mixture of oils. The first varnish was used to preserve mummies. Lac, a resin, when dissolved in alcohol forms shellac. Enamels are mixtures of paint and varnish.

All paints, varnishes, and oils are used either to beautify the surface to which they are applied or to preserve it against wear, decay, weathering, or oxidation.

Why are plant products useful? Because most plant products are porous, they are generally good insulators, but resist wind movement poorly. All plant products burn or char and are destroyed by fire. They conduct electricity poorly.

The chief advantages of wood products is that they are cheap and plentiful and provide fairly warm, secure housing at relatively low cost.

Demonstration. What Are the Different Woods Used in Building?

What to use: Wood samples.

What to do: Examine the grain of the wood with a magnifying glass. If the samples are not too valuable, test for hardness by scratching with the grain and across the grain with a nail. Split a piece of the wood. Observe how the wood breaks. Do large splinters form? Is the wood strong or weak? Polish a piece of wood with oil on a cloth. Can you make it shine?

What was observed: Make a table to record your observations.

What was learned: What are the characteristics of each wood?

Exercise. *Complete the following sentences:* The most widely used wood comes from the —1— tree. The commonest hardwood is —2—. The annual rings of growth give wood its —3—. —4— is formed by gluing together thin strips of wood called —5— under pressure. —6— are made by pressing together wood, cane, or flax fibers. Plant products are good —7— of heat and electricity. —8— contain mineral pigments, while —9— contain resins dissolved in oil. —10— consists of resins dissolved in alcohol. The most important plant material used in building is —11—.

Science activity. Make a collection of wood samples used in your community. Varnish one-half of each sample.

2. What earth materials are used in housing?

Courtesy Louisville Cement Company

Mortar is used to form a bond and seal the spaces between bricks.

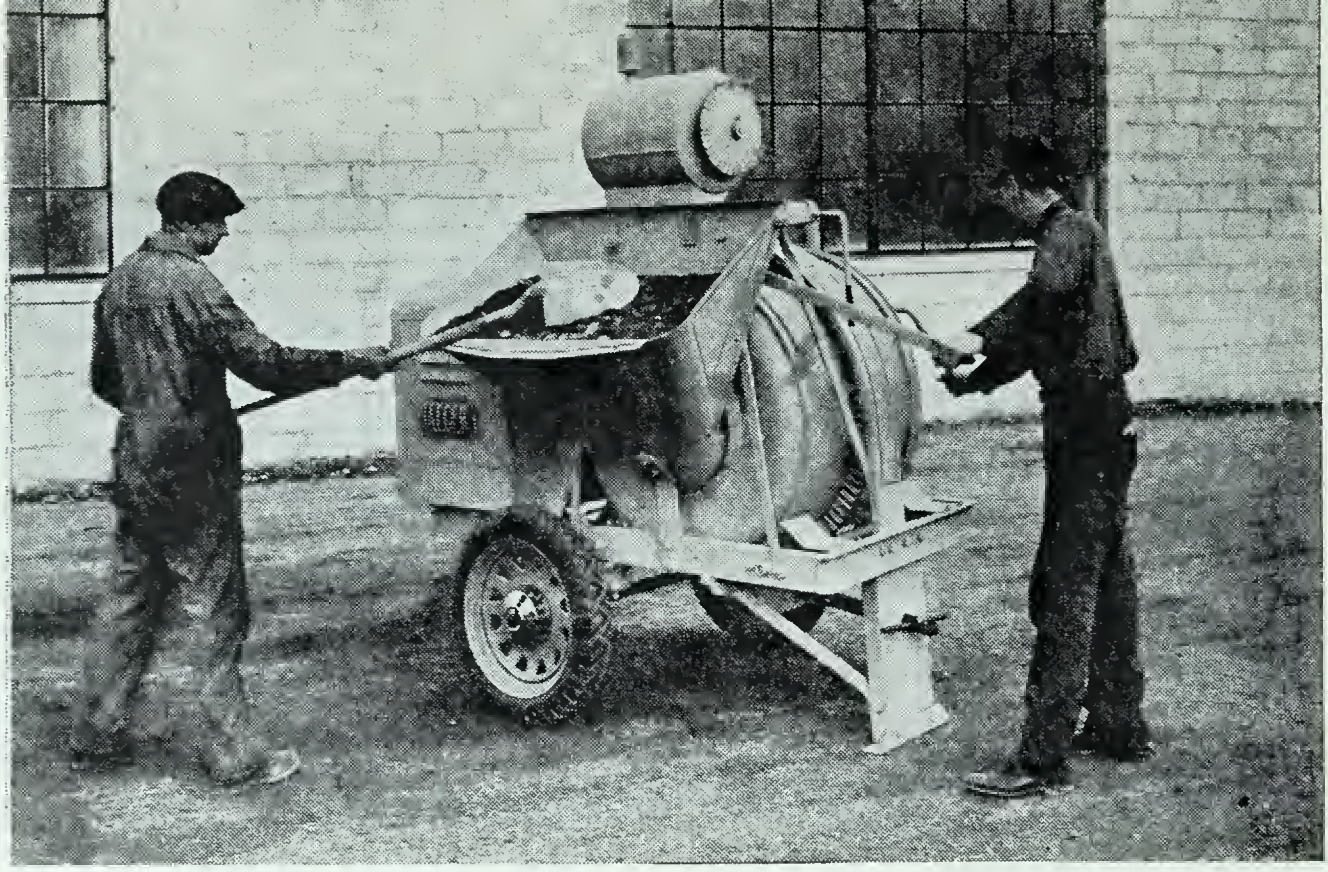
Because stone, cement, brick, glass, and mica are made of materials commonly found in the earth they may be called earth materials. The earth materials are very different in their physical and chemical properties from the plant products. They conduct heat much more rapidly than do the ordinary vegetable-building products. Being brittle, they are extremely hard to work, and cannot easily be changed in form after they are ready for use. Earth materials in general are durable, being resistant to fire and to the slower changes of decay and weathering. Besides this, they are not attacked by insects, and they are extremely poor conductors of electricity.

How is stone used in building? The commonest building stone is granite. Granite is hard, coarse-grained rock which can either be given a glasslike polish or left rough. It is the most durable of the common building stones, and next to marble the most beautiful.

Sandstone is easily worked but weathers and crumbles fairly rapidly. Limestone is similar to sandstone in ease of working and relative lack of durability, but differs in appearance. Limestone often is light colored, tending toward gray and yellow; while sandstones are often darker, tending toward red and brown in color.

Marble is the most beautiful of the building stones. It takes a glasslike polish, and because of its great variety of colors and patterns it lends itself to almost every type of decorative use.

Stone is removed from the earth in quarries. The quarry is usually equipped with cranes, blasting equipment, and drills and saws. The stone is cut from the bedrock and



Courtesy The Jaeger Machine Company

In a concrete mixer cement, sand, gravel, and water are stirred into a uniform mixture.

broken or cut into convenient-sized pieces. The stone then is lifted from the quarry and cut or polished as required.

How are cement and concrete made? Portland cement, which is used in making concrete, is made from limestone mixed with the right proportion of clay. Gypsum, a mineral, is added to the mixture after the limestone has been heated in a kiln until it crumbles to a powder. The three materials are ground very fine, sifted through silk, and sealed in waterproof bags. Masonry cement is similar to Portland cement.

Concrete is an artificial stone made by mixing cement, sand, gravel, and water. A mixture suitable for use around the home consists of one part cement, two parts clean, sharp sand, and four parts gravel. Water sufficient to make a thick "mush" is used. The mixtures richer in cement are more nearly waterproof.

Concrete is poured into forms made of lumber or plywood. The steel bars used for reinforcement are placed inside the form, and the wet concrete is poured in. It hardens enough in a few hours to permit removal of the forms and continues to harden for weeks. Concrete obtains its strength from the entangling of crystals of cement around sand.

Concrete is one of the most important building materials,

Courtesy Portland Cement Association

It is difficult to recognize the substantial old barn above as being part of the modern house below. The walls of the remodeled house are covered with stucco.

for it is used in basement walls, for floors, for entire houses, for walks and steps, for posts, for septic tanks, for well covers, and for bird fountains.

A form of cement is applied to exterior walls as stucco and to interior walls as plaster. Plaster may also be made of sand and lime, mixed at the place of use. Plaster and stucco are supported upon lath. Lath may be strips of wood or a wire netting. The wet plaster is laid on the lath with a trowel (a flat blade) or by compressed air. It flows into the spaces behind the lath and locks itself into place as it

hardens. Masonry cement is used to hold together tiles, bricks, concrete blocks, glass blocks, and stone.

How is glass made? One kind of glass is made by melting together at high temperatures sand, lime, and washing soda. Other materials may be added to give color or special properties. The melted glass may be poured into forms for making blocks, or it may be poured on a long table to be rolled out, polished and formed into plate glass. The ordinary, uneven glass we use in windows is blown into large bubbles by machines, and the bubbles are cut and flattened out while hot. Glass blocks are made in two pieces, and the pieces are melted together. They are hollow.

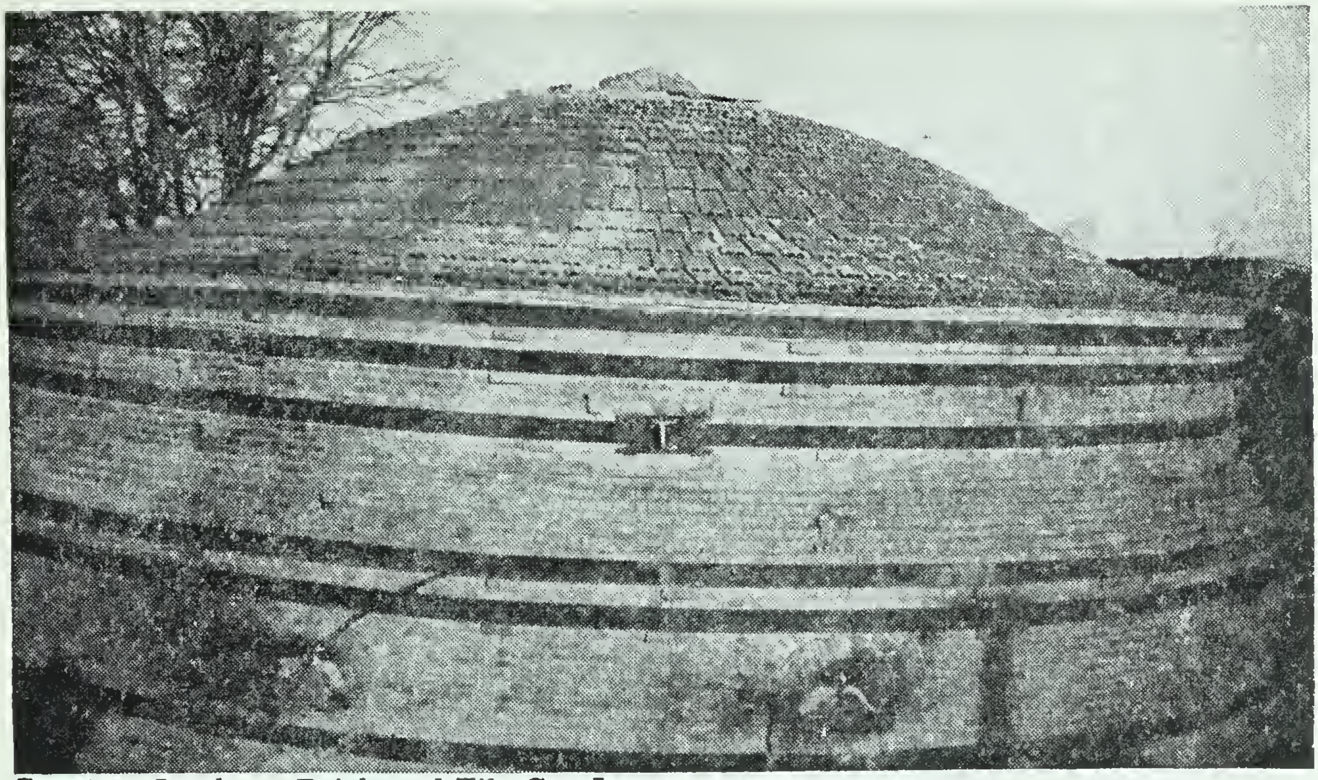
Glass is ordinarily brittle, but by special processes of a slow cooling called annealing, it is made strong enough to be used in springboards. If a piece of glass is viewed through one piece of polaroid while illuminated by light shining through another piece, the strains in untreated glass produce rainbow hues, and weak spots can thus be detected.

Glass wool, made by forming glass in threadlike filaments, is used for insulation in stoves, in walls, and in refrigerators.

How are brick and tile made? Modern brick is made from pure clay, moistened and worked to make a heavy, uniform mass. The moist clay may be pressed through openings the size of a brick, so that it comes out as a thick ribbon. The ribbon is then cut into blocks to form the bricks. Individual bricks may also be pressed into molds. The uniformity of the moistening process is a determining factor in producing any good brick. The bricks are placed in ovens called *kilns* and heated until the clay is baked into a hard, rocklike material.

To make tile, a pure, white clay is formed into bricks. Then a glaze of glasslike ingredients is added and baked on the surface of the tile. Color may be added to tile in the glazing process.

Brick is used for foundations, for chimneys, for lining furnaces, for walks, and for entire houses. Tile is used in finishing bathrooms and for decorative effects. Porcelain, a fine grade of tile, is used in making toilet flush tanks, bowls, bathtubs, and sinks.


Courtesy Isenhour Brick and Tile Co., Inc.

In the brick kiln water is driven from the plastic clay, which is baked to form a hard rocklike material.

How are whitewash and creosote made? Whitewash is made from lime and water, with sufficient glue added to make it stick. Creosote is a coal-tar product much used as a preservative for foundation timbers, posts, poles, and railroad ties. Both creosote and whitewash are used on barns and chicken houses because they kill lice and are of value as disinfectants.

What are mica and asbestos used for? Mica is a mineral which occurs in nature as thin transparent sheets. It is used in electrical instruments for insulation against electricity. It is also used in houses for heat insulation. The mica for insulation is heated and expanded much as corn is popped. The expanded mica looks almost like cork, and when used for insulation it is poured between the walls.

Asbestos is another mineral that is used for insulation. It occurs naturally in white, fibrous rocks. The fibers when separated are blown loosely into walls or made into quilts or pressed into paper. Asbestos is a very poor conductor of heat and is fireproof. Asbestos shingles, made by pressing the asbestos into boards, are extremely durable and fire-resistant.

Demonstration. How Are Brick and Concrete Made?

What to use: Clay, burner and stand, can, cement, sand, gravel, chalk box or wooden form.

What to do: Moisten the clay slightly, and knead it into a plastic mass. Add only enough water to make a stiff, sticky mixture. Press it into the form. Place the small brick on a piece of sheet metal over the burner, and cover it with the tin can. Arrange for steam to escape from time to time.

Mix cement, sand, and gravel, and make concrete. Pour it into the form, and let it harden. After a day or two observe the concrete. Break it.

What was observed: Describe the changes that take place in the materials as they harden.

What was learned: What are the advantages of making artificial stones over using natural stones?

Filmstrip: Vermont Marble. S.V.E.

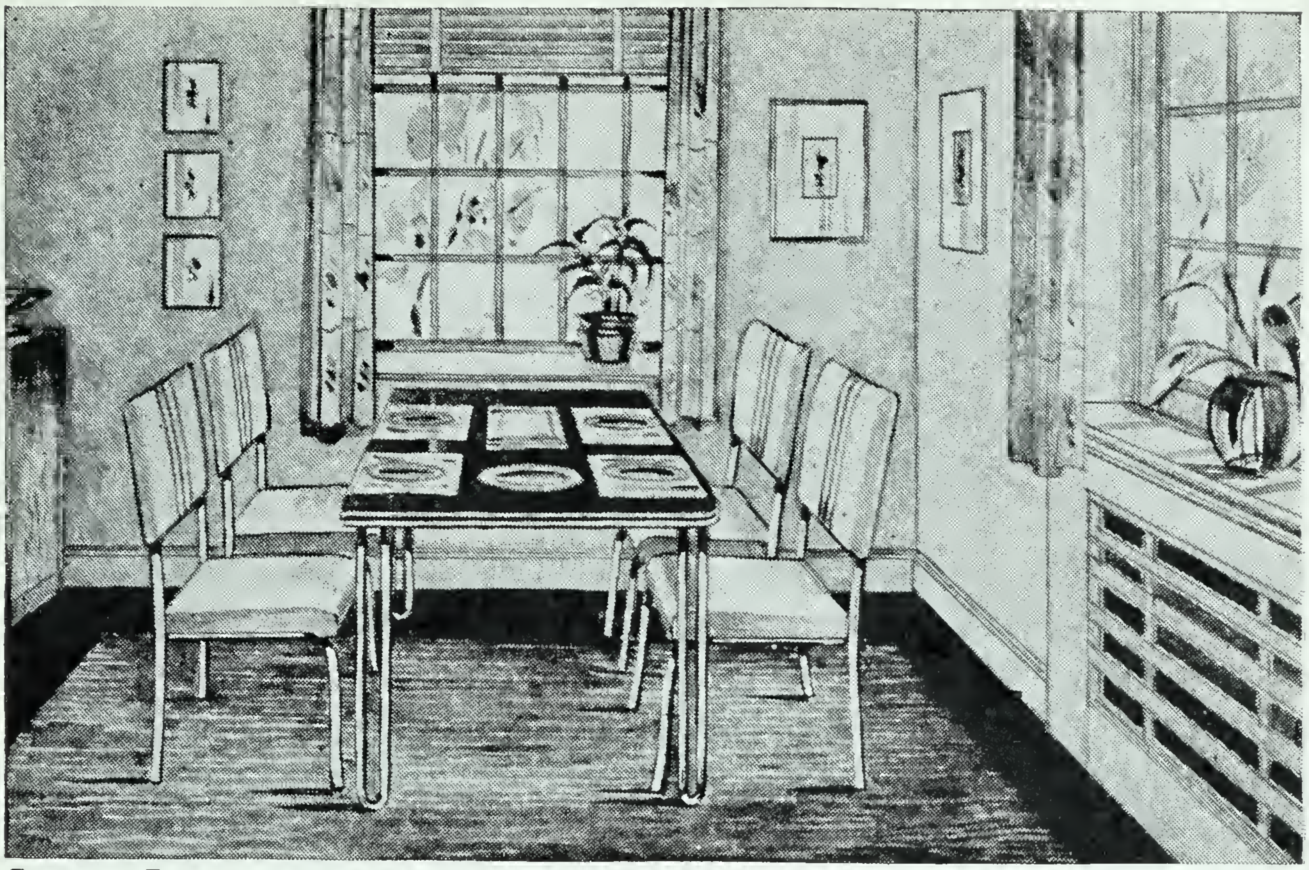
Exercise. *Make a table by ruling your paper into eight columns. Head the columns as follows:* MATERIALS, SAND, LIME, SODA, CLAY, GRAVEL, MICA, ASBESTOS. *List 10 or more building materials at the left of your paper in the column headed* MATERIALS. *Make a check mark in other columns to show of what earth materials each building material is made. For example,* "Plaster" might be followed by checks in the columns headed SAND and LIME.

Science activity. Make a collection of all the earth products mentioned in this problem, and label the specimens.

3. What metals are used in building houses?

The average small house contains a surprising amount of metal, the total being estimated to be almost four tons. Nails and screws, wiring, plumbing, lath, hardware, and the heating plant are ordinarily made of metal. Large apartment buildings are frequently made with a framework of steel. Sheet steel is being used successfully for walls in factory-made houses.

How is steel used in buildings? The modern large apartment and office buildings are often built on the skyscraper plan. The framework of huge I-shaped steel beams is riveted or welded together to form the building. Then the walls, floors, and other parts of the building are placed upon the framework.



Courtesy Royal Metal Mfg. Co.

Old materials are employed for new purposes. This breakfast set is made largely of steel tubing.

Many smaller houses are in part supported upon steel beams and supports.

Sheet metal is usually worked in rolling mills and shaped by hydraulic or mechanical presses. Because it is impossible for workmen to transport heavy metalworking machines to the site of the house under construction, steel houses are now being made in factories. The sheet metal walls are made in panels. The wall panels are insulated. Some panels contain doors, and others contain windows, all being of metal except the glass.

Metals are excellent conductors of heat and must be insulated with other materials, such as wood fiber, asbestos, or dead air. Metal, on the other hand, resists wind better than any other material except glass. Metal can be polished to reflect heat. Research in better methods of combining steel with other materials is constantly going on. Eventually it should be possible to buy a metal house in a factory and have it shipped ready to stand up on a foundation.

What are the uses of screws, nails, bolts, and rivets? Screws, nails, and rivets are cut from wire and hammered

into form by machines. Bolts are made from steel bars. Nuts are cut from blocks of steel. Almost all houses are fastened together to some extent by these common steel devices.

Where is metal used in heating systems? Cast iron is commonly used in radiators. It is a good conductor of heat and is strong enough to withstand years of use. Pipes used in heating systems may be of iron or steel. Most furnaces are made of iron. Pipes of the hot-air system are almost always made of galvanized sheet metal.

Galvanized iron is iron dipped into hot zinc, which forms a protective coating over the iron and prevents rusting. When iron rusts, the rust scales off, and rusting proceeds faster from the roughened surface. When zinc rusts or oxidizes, the oxide forms a thin, air-and-water proof film over the zinc. Because zinc and iron are electrically similar, they do not form wet cells when water or salt solution falls upon them. Galvanized iron is therefore durable and rust resisting.

Where is copper used in the house? Next to iron, copper is perhaps the most important metal used in building. It is an excellent conductor of heat and electricity and is resistant to oxidation.

Current is brought to houses through a lead-covered copper cable. Where the wire enters the house, it may be led into pipes called conduits. The pipes are grounded to prevent electricity from setting woodwork on fire. The house-wiring may also consist of flexible, steel-wrapped copper cables. The wire is less likely to be broken or cut if it is properly protected.

If copper had no other use than for wiring it would be indispensable in modern houses. But it is used also in heating coils in the water heater and for roofing.

Where is lead used in the home? Lead, although it is valuable when properly used, is poisonous. Small amounts may accumulate in the body over long periods of time, until enough is present to make one ill. Lead, therefore, should never be used where it can come in contact with water or food that will be used in the home.

Lead is used in sewage connections and pipes. It is easily worked and is useful in closing joints in sewer pipes. Some pipes are fitted together by a threaded connection. Others

are joined by melted lead poured over the joint and wiped smooth with a waxed cloth. The low melting point of lead makes it valuable for this use.

A lead compound, litharge, is frequently used to close joints in pipes. It is safe only on sewage pipes.

How is aluminum used? Aluminum has the ability to resist oxidation for a long time and may be rolled into very thin sheets. Consequently, aluminum foil is sometimes placed in walls as insulation. It resists wind well and reflects radiant heat.

Aluminum is also used in window frames, as is steel. Metal frames are often desirable, for they may be made to fit more tightly than do wooden frames.

What is hardware? Hardware consists of doorknobs, locks, window pulleys, hinges, window catches and handles, latches for cabinets, and all the numerous small articles of metal used in so many places in the house. Almost all hardware is made either from soft steel or from brass. There are thousands of sizes and varieties of house hardware.

What metals are used in paint? There are two general types of metallic paints—one in which metals are combined in chemical compounds, the other in which free metal is applied.

The common household paints are made of the oils into which finely ground lead, zinc, or titanium compounds have been mixed. Lead carbonate, lead oxide, and zinc oxide are commonly used in outdoor paints. No lead paint should be used in the kitchen or bathroom or in any place inside the house where children might come into contact with it.

Paint hardens because of oxidation and other chemical changes which take place in the carrying oils. The chemistry of paint hardening is not well understood.

Aluminum paint is made by putting finely divided aluminum metal in suspension in a quick-drying oil. The oil forms a film to hold the aluminum in place and acts as a protective coating. Gilt paint is bronze metal in oil.

Some red barn paints contain iron oxide which, because of its durability and low cost, is satisfactory for use on barns.

What are the useful properties of metals? Metals, because of their ability to conduct heat, are generally used in

heating devices. They are fireproof and resistant to weathering in varying degrees. Metals are exceptionally strong, but they bend easily and warp under pressure. Dents in metals are straightened with difficulty. Metals may be drawn into pipes for steam and water.

The difficulty of working metal into desired forms is one of the most important factors limiting its use in building.

DEMONSTRATION. HOW DOES METAL COMPARE TO OTHER MATERIALS AS A CONDUCTOR?

What to use: Wood samples, glass and stone, pieces of two kinds of metals.

What to do: Place two samples of wood, the glass and stone, and two pieces of metal upon a hot radiator or other hot surface. Touch each in turn. Repeat the experiment, placing the articles upon a cake of ice.

What was observed: List the six articles in order of their ability to conduct heat, starting with the poorest conductor.

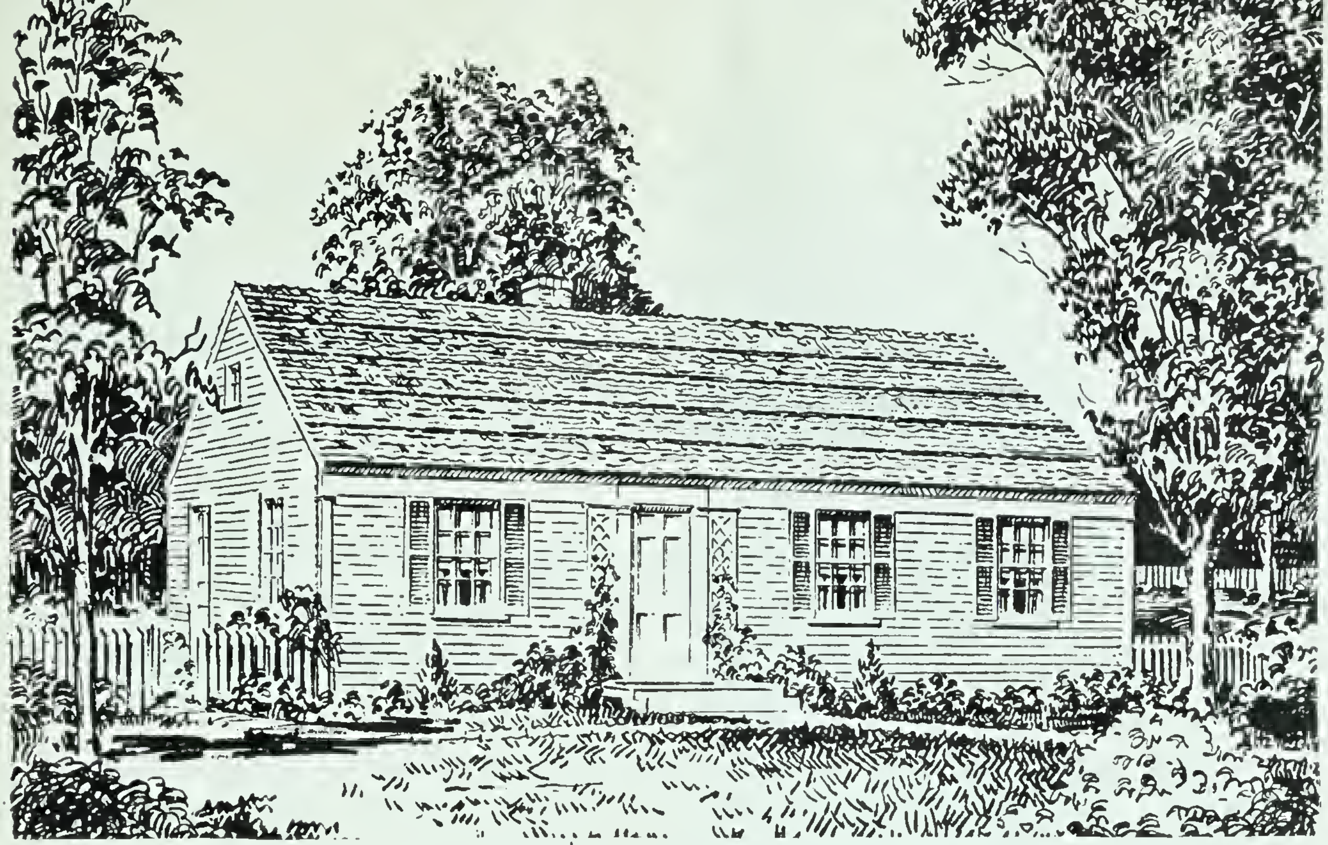
What was learned: Is metal a good conductor of heat?

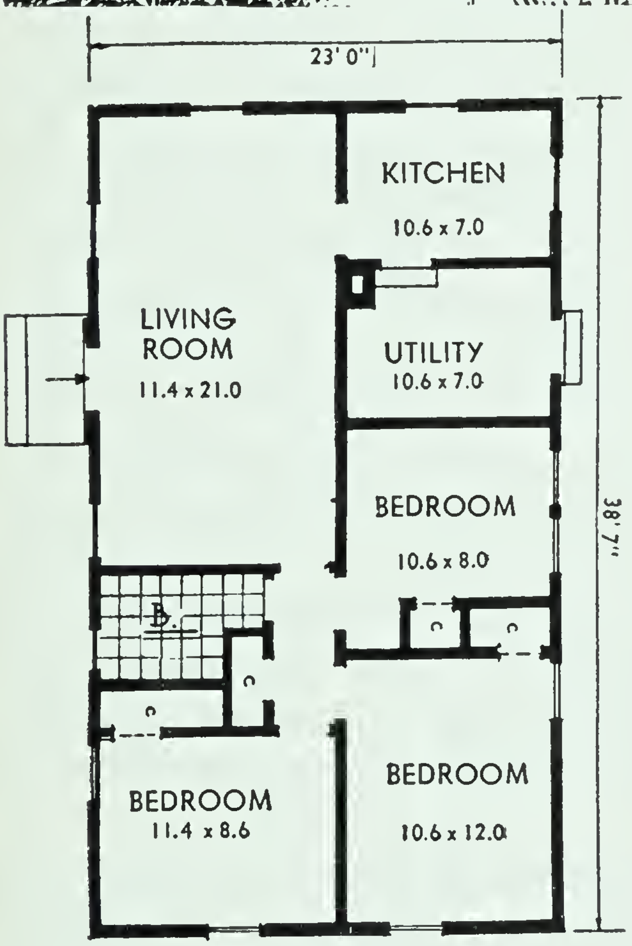
Exercise. *Make a table by ruling your paper into seven columns. Head the columns as follows:* IRON, LEAD, ZINC, ALUMINUM, COPPER, BRASS, OTHER METALS. *In each column write the names of as many common building articles as you can. You should have not less than 25 articles in your list.*

Science activity. Make a collection of metals and metal products, grouping them according to the kind of metal from which they are made.

4. How are houses planned for use?

There are in general two ways of planning a house. One way is to decide on what type of exterior one wants. Then the interior of the house is made to fit into the exterior plan. In functional planning the desired rooms are fitted together in the most convenient and economical arrangement. The exterior of the house is balanced only if the interior plan demands it. Since a house is to be planned for the people who live in it, the interior should be the important consideration.





Courtesy National Lumber Manufacturers Assn.

The architect draws a floor plan and a sketch showing the appearance of the outside of the house. The plan of the house determines to a large extent all other factors in building a house.

What does space cost? The cost of enclosing space depends largely upon the materials used to enclose it. Whether the space is used for living, for bathrooms, for halls, for chimneys, for inside walls, or for spaces for doors to swing into makes little difference—the cost remains unchanged. The cost generally ranges from twenty-five to fifty cents per cubic foot in average small houses.

The average family in the United States should spend about $3000 for its house. Such a house should rent for not less than $27.50 nor more than $30.00 per month. Many people need a house which costs about $2000 complete. Only about 10 per cent of the population can afford to live in houses costing more than $5000. Thus you can see that the average house plan appearing in magazines has little value

to most of us. Rent is about 1 per cent per month of the sale price of the house.

What are essentials in a house? Certain things are essential for decent housing. There must be a kitchen and living room. A bathroom is also essential. A bedroom is needed for each one or two members of the family, according to sex and age.

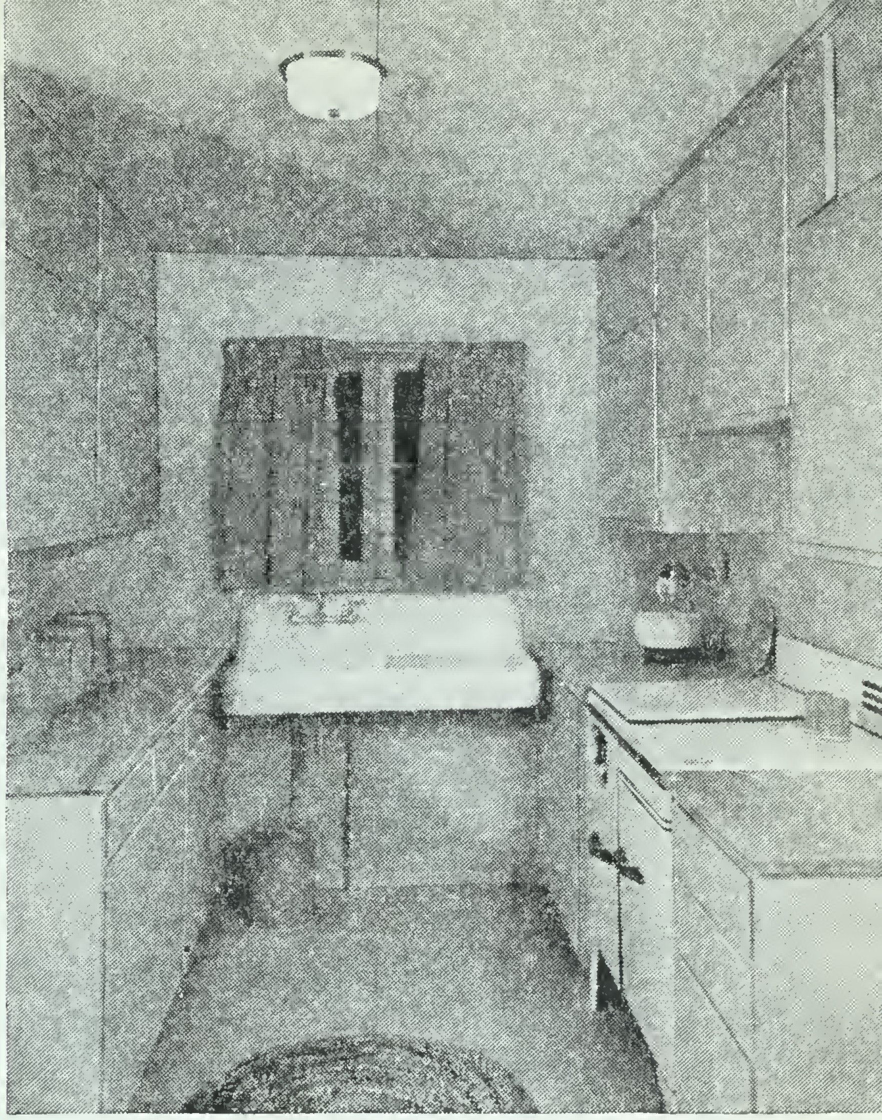
It is desirable to have storage space and either lockers or closets within the house. An entry hall is highly desirable in cold climates. It is essential, if any kind of heating system other than a stove is used, to have a space for the furnace—either a separate room or a small basement space.

What things are not essential in homes? We have been trained by high-pressure selling methods to expect a home to contain many things which may be attractive or desirable, but certainly are not essential. Common nonessentials include the fireplace, the porches, hallways, sunrooms, and French doors. The fireplace is an inefficient heater and a source of smoke and dirt. Porches are useful in few parts of the United States, but in these places it is better to have the windows in the living room removable. The living room then becomes an outdoor living space. Large hallways are not essential and are just as expensive as any other space. Stairways are just as expensive as living areas, and are a serious cause of falls. However, a two-story house may still be more economical to build than a one-story house containing the same number of cubic feet of space. The sunroom is rarely useful, being too hot in summer and too cold in winter for any use.

What are undesirable features of houses? Certain things added by poorly trained architects in an attempt to make a house decorative are definitely undesirable. Among these undesirable features are fake or false gates, long sweeping "roof lines" stuck on the walls, overhanging roofs which shade the windows, dormer windows which are practically useless for admitting light, and a large number of other money-wasting and useless gadgets. An overdecorated house is often built of poor quality materials for quick sale to people who do not realize what a good house really is. Much flashy ornamentation is used to hide poor quality.

Why should we study house plans? The planning of the house is so important that it actually determines to a large extent the happiness and comfort of the family. Poor planning results in overwork of the mother, lack of comfort, embarrassment, and shortage of money because of waste.

There has never been a completely good house plan worked out—one which conforms to human needs and scientific principles. It is doubtful that such a plan is possible, for all plans must compromise between desires, needs, and practical limitations of materials and costs.



Courtesy U. S. Forest Products Laboratory

A small kitchen saves both material in building and labor in operating the home. This kitchen has many features available in the economy house.

The house plan shown on page 421 provides a house at a cost of less than $2800. It is made of lumber. Although this house lacks some things that people like, it omits no essentials. It has no basement and no dangerous stairs. The furnace, hot-water tank, and laundry are in the utility room. Three bedrooms offer ample space to accommodate the average family. The bedrooms have long, clear wall spaces for placement of beds. The kitchen and utility room are side by side, an arrangement which saves steps and plumbing costs. Closets are ample. Two of the bedrooms have cross ventilation, which is desirable in a low-priced house. The number of doors is kept down, which is desirable, for doors swing into living space and make it useless.

This house is badly lighted. The living room has only three small windows, and the kitchen has only two. The use of cross ventilation produces undesirable cross lighting. There is no entry hall. The back door opens into the utility

room—a good feature, for it is convenient for laundry and protects the kitchen from cold air.

The outside of the house is attractive, although the shutters are purely decorative. This house does not represent the best modern housing, but does offer a good house at a reasonable cost.

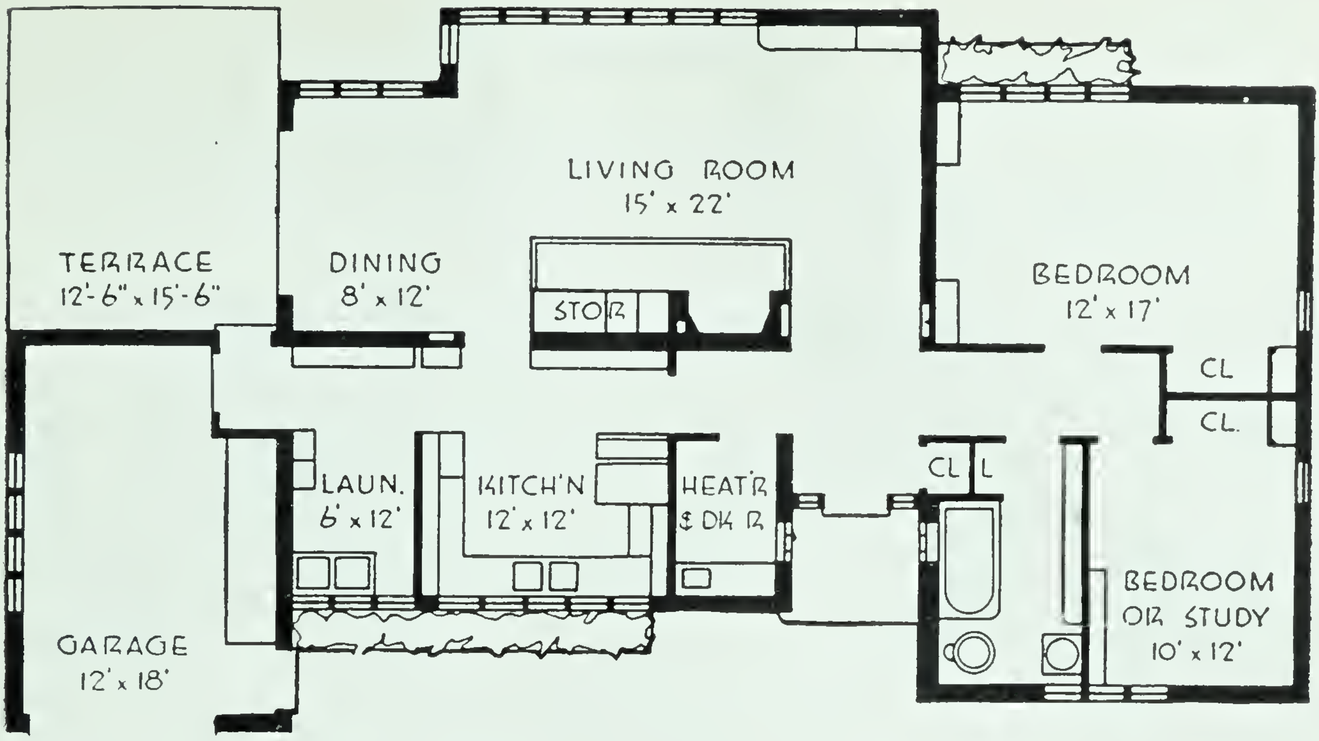
There are certain points that are characteristic of badly planned houses. Some of these are as follows: rooms requiring plumbing located too far apart; an unusual number of halls or halls that are unusually large; several chimneys; too many doors within the house, breaking wall spaces and requiring space for the swinging door; a bathroom situated so that a person cannot go into it from the bedrooms without being seen from the living rooms; small windows, placed too low in the wall or placed where they will cause glare; a kitchen that is too far from front entry and bathroom; closets or lockers that are too large or too small or located where closet doors break useful wall space.

If the house is well planned, all these questions may be answered in the negative:

Are dining space, cupboards, sink, and stove arranged carelessly with no thought of saving steps? Are kitchen machines and cupboards arranged so that food is moved from storage to table in a roundabout way? Does the house have many "trick" features, such as dormers, bay windows, complicated built-in features, fancy trim, and fireplaces? Is space wasted in large porches or sunporches, by fireplaces, by extra stairs and halls, or in large bathrooms, dressing rooms, and little corners of space unfitted for any real use? Are upstairs living spaces wastefully duplicated in the basement? Is the basement space wasted because of dampness? Is the attic too large?

Do many people live in apartments and multiple dwellings? Many people living in cities have never lived in a separate dwelling but always in apartments. An average-sized apartment building contains perhaps 20 apartments. Such a building houses more people on one lot than are housed in a small town in two blocks. Some apartment buildings house hundreds of people.

A very poor type of apartment, lacking sanitation and



Courtesy *Popular Science* magazine

This prize-winning plan provides for no more essential features than does the first plan. It does provide for many luxuries and conveniences. The cost of this house is about $7000.

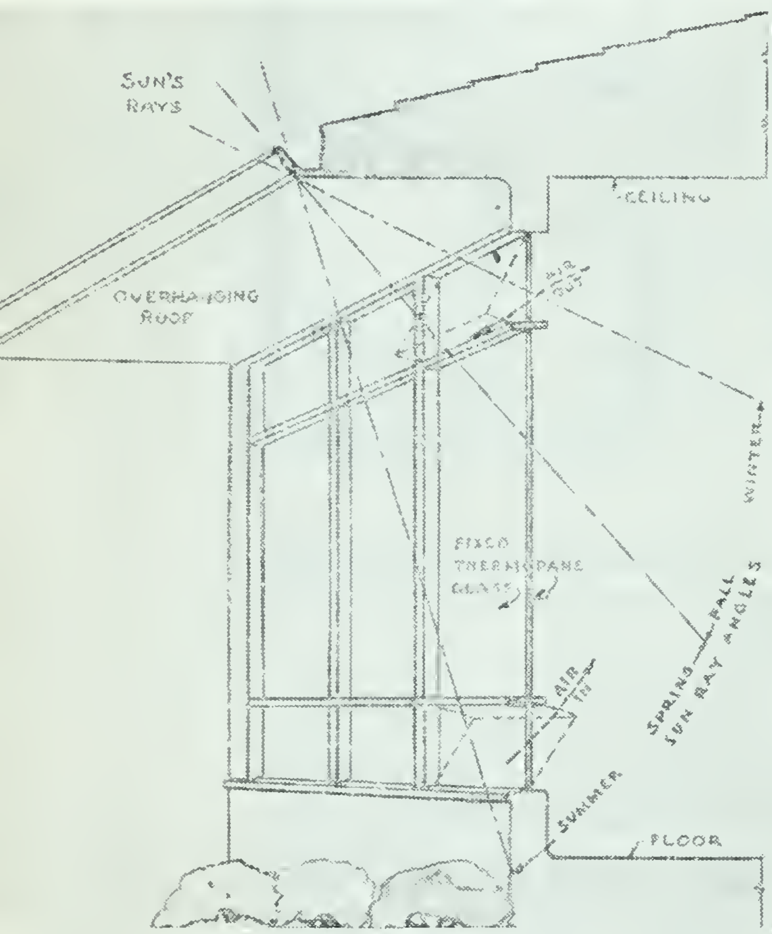
living space, is called a tenement. In such buildings usually one bathroom serves many families, garbage cans stand in the halls, and no screens are used on windows. Noise, lack of privacy, and uncleanliness are the most noticeable features of these tenements. The health of people living in these buildings is generally below average; and the death rate, particularly of babies, is above average.

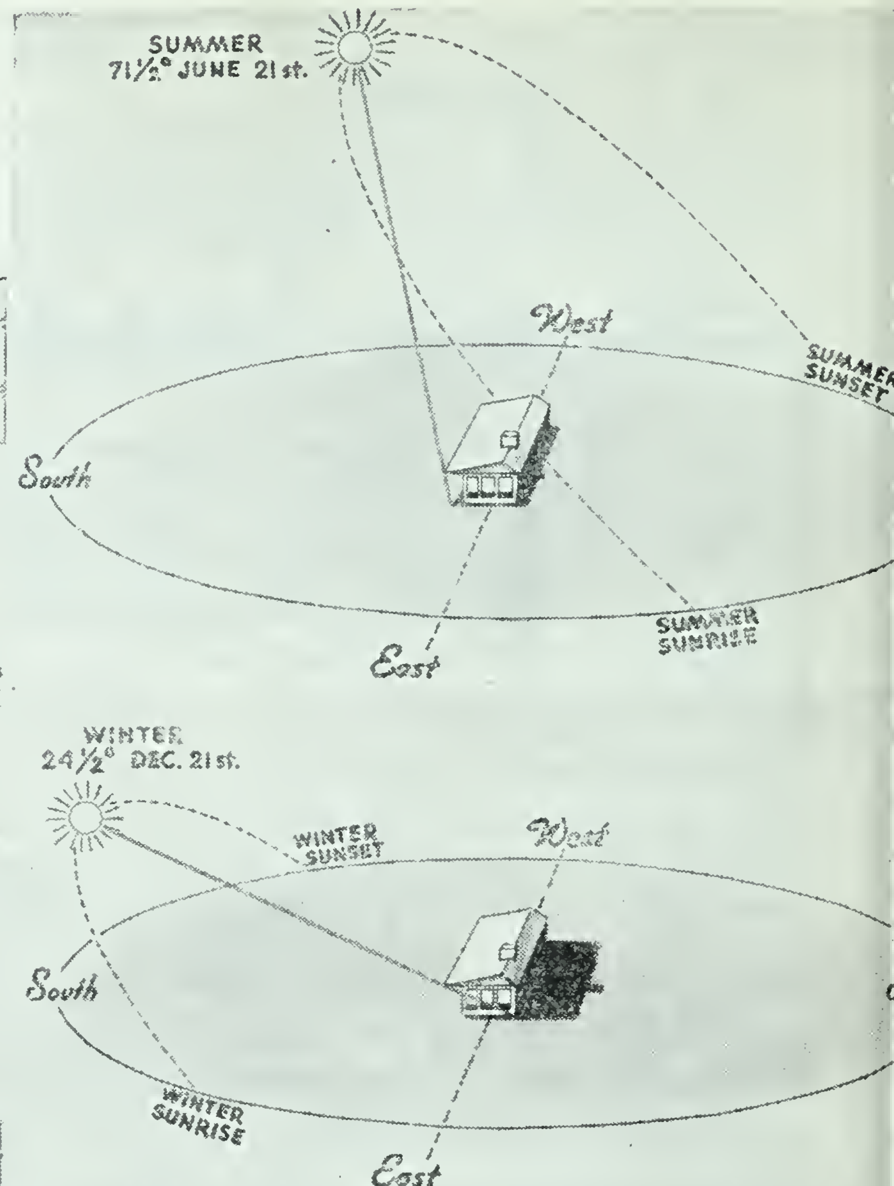
A well-located, clean apartment has many advantages over a single dwelling. Cost of heating and of caring for such items as cleaning, plumbing, refrigeration, and repair are reduced. The apartment operator can hire skilled labor and buy in larger quantities to provide good service economically.

Exercise. *Make a table by ruling your paper into four columns. Head the columns as follows:* ESSENTIAL, DESIRABLE, LUXURY, UNDESIRABLE. *List in the proper column the following words:* bathroom, kitchen, living room, slate roof, many doors, stairs, dining room, one bedroom per person, laundry, furnace heating plant, stone gate on house, brick court, cross lighting, large windows, sunroom, shutters.

Science activities. 1) Obtain floor plans from papers or magazines. Shade with pencil lines all halls and stairways and all spaces where doors swing. Shade in black the fireplace and sunroom.

THE SOLAR HOUSE





Courtesy Libbey-Owens-Ford Glass Company

At the top left is a house with a solar window made of double glass and with an overhanging roof to protect against summer sun. At the top right is shown the difference in elevation of the sun in June and December at Chicago. Winter sunshine falls far into the rooms, heating the house enough to save much fuel. Below is the south side of a solar house.

Draw in red the paths through various essential rooms, as from the kitchen to the living-room door. Consider the questions asked in this problem. Select the least wasteful plan.

2) Draw an original house plan to scale.

5. How is the good house constructed?

The good house is so constructed that it offers the greatest possible amount of protection to those who live in it. It must protect not only from cold but also from excessive heat. It must protect against uncontrolled drafts, dirt, and noise. It must offer protection from rats, mice, flies, mosquitoes, ants, and termites. It must resist strong winds, fire, and earthquakes. It must be easy to clean and must require little upkeep. Unfortunately there has never been a house constructed which meets all these requirements.

Where is heat lost? Heat is lost in three ways: by radiation, by conduction, and by convection. Radiant heat is lost from all hot surfaces. Radiation is decreased when surfaces are polished or are light in color. Heat is conducted to some extent by all materials. Heat is also lost by convection caused by air movement within the house, and by winds from outside the house. It is estimated that on a windy winter day wind pressure changes the air in the average house quite completely every two or three hours, with all doors and windows closed. The air leaks through pores in wood, brick, or concrete and through cracks.

Heat is lost about equally from the roof, from the walls and floors, and from windows and doors.

To prevent loss of heat through the roof, an attic is ordinarily used to provide a dead air space for insulation. An attic is a poor insulator. Effective insulation may be placed on the attic floor, however. But insulation prevents only conduction. Heat is lost in moving currents of warm air which escape through ceilings and roofs which are not airtight. Many modern houses have no attic but are built with flat roofs and are well insulated and made water- and airproof. Such roofs may be cooled in summer by running water over them. The water need not be wasted, for it may be used later for the lawn. It is easier to plan a flat-roofed

Courtesy Pittsburgh Plate Glass Company

Here a huge window opens into an ornamental outdoor garden. The drape can be used to provide privacy when desired. The mirror on the fireplace wall brightens the room and makes it look twice as large.

house because with such roofs it is not necessary to fit roof lines and slopes into the plan.

Radiation of heat through the roof may be slowed down in various ways. A roof of polished metal is the best reflector of radiant heat, and one painted a glossy white is next best. Ordinary black or dark roofs reach temperatures of 120 to 135 degrees in summer sun and re-radiate the heat downward into the house. Similarly, dark-colored roofs lose heat more rapidly in winter than do light-colored roofs. Roof color alone can make an indoor temperature difference of 10 degrees.

The usual method of preventing heat loss from walls is by use of insulation, either of the fiberboard variety or of the loose fiber type. Either kind is fairly satisfactory if properly installed. Aluminum foil inside walls prevents radiation. An aluminum-surfaced paper is available to use in combination with other types of insulation. Inexpensive houses often are insulated with paper. Paper reduces the amount of wind blowing through cracks in the walls and provides some insulation. Probably the most satisfactory insulation for new houses is fiberboard or a quilt insulator. For old houses it

is generally easier to install insulation blown into the walls. Such insulation may settle after a time, however.

Floors are frequently insulated only with paper. Although rugs are used for insulation, they are unsatisfactory for that purpose. Rugs cause more falls than do any other objects in the house and are difficult to clean. Only a vacuum cleaner will clean a rug, even fairly well, and vacuum cleaners are expensive. Rugs must be regarded as makeshift insulators at best. There is no really satisfactory floor material available. In many ways, linoleum is superior to wood because of its freedom from cracks and because of its springiness. It is easily washed.

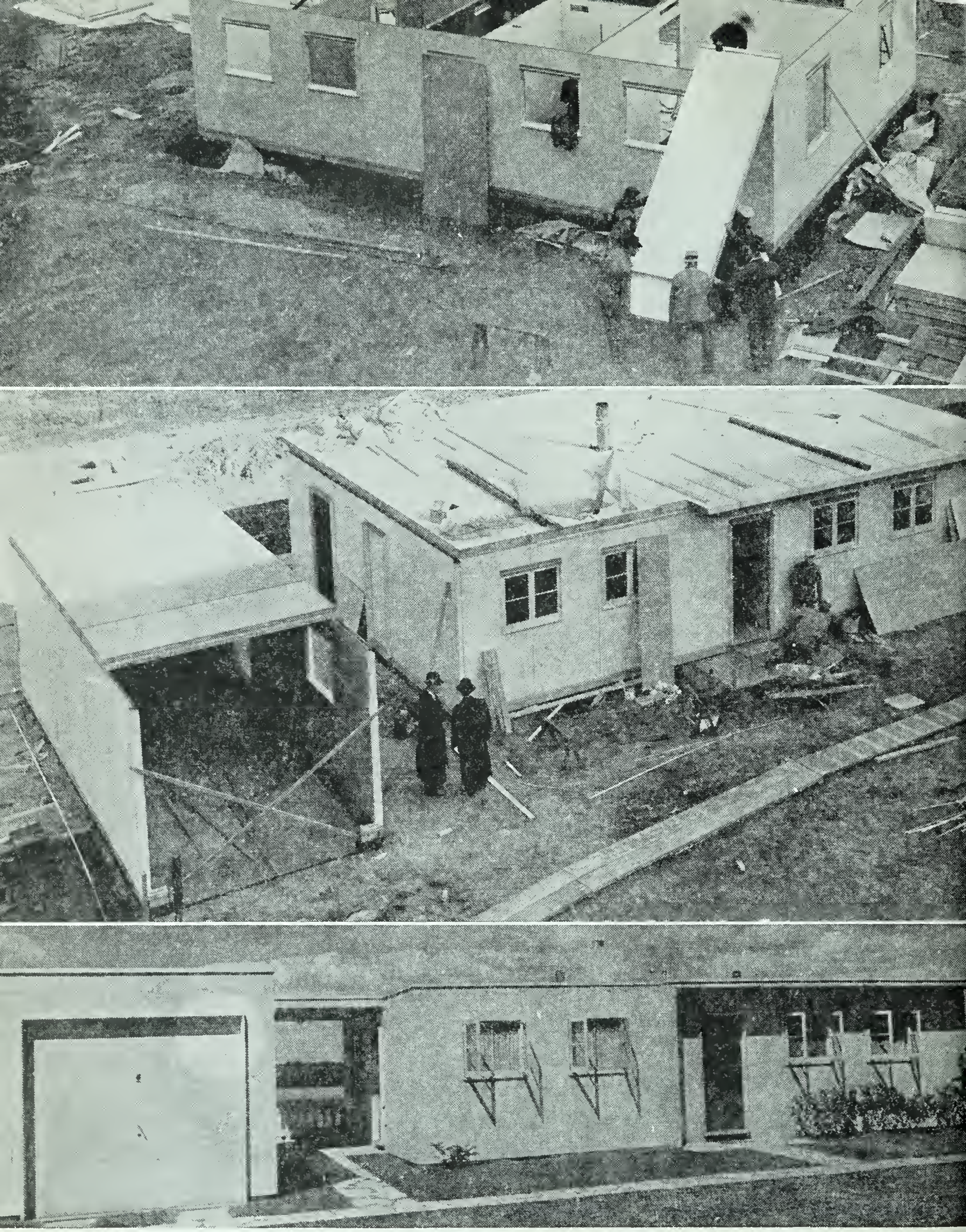
Windows offer a serious problem in heat control. The average window frame is set into a hole in the wall and held in place by sticks and wedges. Wind blows around any such window which fits loosely in its frame. A single pane of glass radiates heat rapidly and conducts it still faster. A makeshift window insulator is the storm window—a second, cheap-quality window placed outside the regular window. Storm windows are superior to no window insulation, for the inner windowpane is almost 20 degrees warmer in zero weather than if no storm window were used. Weather strips around windows help to prevent heat loss. Windows are generally used for ventilation, which complicates the problem still more. All too often windows ventilate the house whether ventilation is desired or not.

Good windows are made with double panes of glass, which are removable for cleaning. A new type of window made of glass block is highly successful. The block is laid like brick and sealed into the wall. Moisture does not condense on it until the temperature is 15 to 20 degrees below zero. One cannot see through such windows nor open them.

To protect against loss of heat from doors, an entry hall should be provided whenever possible, and both the inner and outer doors should be weather-stripped. The door frame should be sealed into the wall when the house is constructed.

Every rule for keeping heat in applies equally to keeping it out.

The ordinary window shade, inside the room, is an absorber of sun heat.



Courtesy U. S. Forest Products Laboratory

Much of the work of building a prefabricated house is done in the factory, and the parts are assembled on the foundation. Prefabricated houses may be of wood, plywood, or metal. In the top photo, the plywood walls are in place; next, the roof and windows are added; and below, the finished house and garage await their new owners.

Can we keep out noise? A house well insulated against conduction of heat is also well insulated against conduction of sound. Fiberboards absorb sound waves, and double windows reduce noise from outside.

Are houses easy to clean? The average house cannot be kept really clean. The cracks in the floors, walls, ceiling, and doors leak dust and hold it when it enters the house. Drapes, rugs, and upholstered furniture constantly hold and then give off dust, bacteria, and fibers.

It should be possible to build floors that can be satisfactorily cleaned with an oil mop. It should be possible to clean a house with hot water from floor to ceiling and to dry it, ready for occupancy, when the cleaning is done. Such a house cannot at present be constructed because the materials available are not adapted to real cleanliness.

Can we keep out insects and animals? The best protection against cockroaches, rats, and mice is an absolutely tight masonry or concrete basement wall, without even a crack in the coal chute or sewer outlet. Flying insects may be kept out by screens over every opening. Both the kitchen and the kitchen entryway should be screened against flies, so that they can be killed before they get into the kitchen. A fine-mesh, copper screen is desirable.

How are houses constructed? Today houses are not bought ready-made. They are built. The time and skill required to build a house is a major reason why our houses are of such poor quality. Each home-builder repeats the errors that have become standard.

Some progress has been made in building ready-to-use houses. Both steel and plywood are used in prefabricated houses produced experimentally. These houses are made in sections and are then set up and joined together in a comparatively short time.

Factory production of houses should lower cost of housing and should provide work for many more men than are now employed in the building trades. Ten million American families need new houses, and another 10 million probably would buy new houses if they could be obtained like automobiles.

When we compare the efficiency of our machines with the

inefficiency of our houses, we realize the cost of failing to apply scientific methods to our everyday problems of living. The only way to bring standardized improvements in housing to the people who need it most—those with low incomes—seems to be to put the tedious work in the factory. A great advantage of working in factories is that work can be carried on all the year around. At present the building season in much of the nation is limited to the summer months.

Demonstration. What Is the Effect of Insulation?

What to use: Three 250 cc beakers, two 400 cc beakers, boiling water, paper, aluminum foil (from candy bar), small board, metal can cover, thermometer.

What to do: Prepare one 250 cc beaker by wrapping it in paper and placing it inside the 400 cc beaker. Prepare a second 250 cc beaker by wrapping it in aluminum foil and placing it inside a 400 cc beaker. Leave the third 250 cc beaker unwrapped. Pour about 200 cc of boiling water into each. Cover the first with the board, the second with the metal cover, and leave the third uncovered. After 10 minutes measure the temperature of each beaker of water.

What was observed: Record the temperatures.

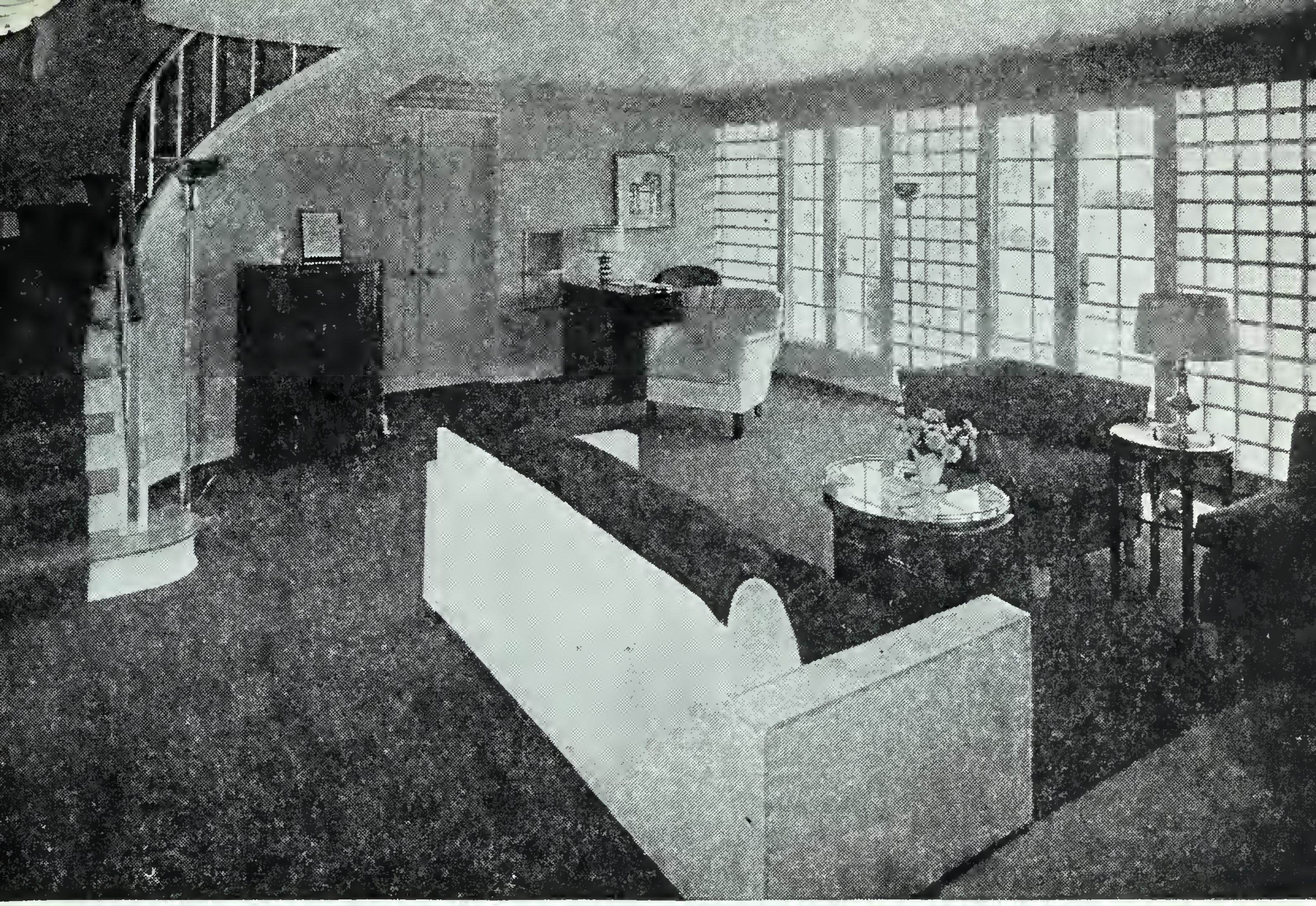
What was learned: Which method of insulation was superior? Is insulation superior to no insulation? What was prevented by the insulation?

Exercise. *Complete the following sentences:* —1— is any material placed between walls to prevent loss of heat. Dead air is a good —2—. Insulation prevents loss of heat by —3—, aluminum foil by —4—, and sealing doors and windows by —5—. Floors properly —6— do not need rugs. When it is zero outdoors, the inner pane of two panes of glass is —7— degrees warmer than a single pane. A roof should be —8— in color.

Science activity. Make an insulation collection for the school, classifying insulators according to type of heat loss prevented.

6. How is the house planned for good lighting?

It is somewhat doubtful that a house can be satisfactorily lighted by windows at all. Windows are poorly placed for distributing light in the room, and the source of illumination —daylight or sunlight—is so unreliable that it cannot be



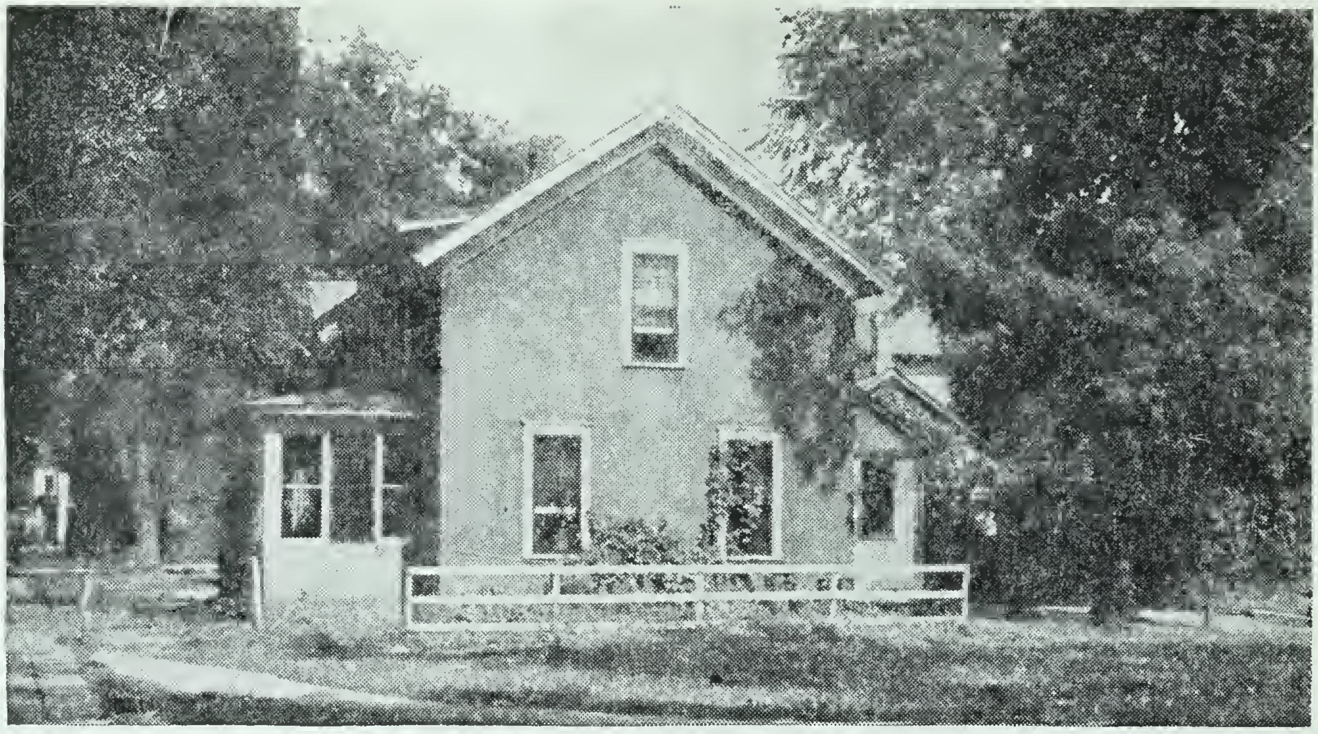
Courtesy Owens-Illinois Glass Company

This wall of glass blocks and the French doors make this a well-lighted room. What sources of glare do you see in the picture? Are French doors satisfactory in the North? Find the four lamps.

depended upon. When the sky is full of flying clouds, the brightness of light at a window may change in a few seconds from two foot-candles to more than 2000 foot-candles. Direct sunlight causes glare spots which cannot be controlled by ordinary shades and curtains. Yet, because of the cost of satisfactory artificial light, most people will continue to use daylight for lighting.

How large should windows be? There are quite definite rules for proportions between window area and floor area, although these rules may not mean much. On a dark day no practical amount of window area will provide enough light; and on a bright day a small window area will provide more light, if it is properly diffused, than is needed.

The rule is that the clear glass of the window should be equal in area to one-fourth of the total floor area. That is, a room 12 by 18 feet has a total area of 216 square feet. One-fourth of 216 is 54. An ordinary window is 2½ feet wide and 5 feet high. More than four such windows are



The typical small house is poorly lighted. The windows in this one are badly placed, some of them opening on a closed porch. Shades are drawn from the top of the windows.

needed for a 12-by-18-foot room, if no curtains or drapes are used.

How may light be controlled? The means of controlling light in general use are really methods of shutting it out. The following experiment, summarized in the table, was performed by placing a light meter on a table three inches from the sill of a west window on a bright day.

CONDITION OF WINDOW	BRIGHTNESS OF LIGHT	
	10:30 A.M.	1:50 P.M.
Window bare and open	90 foot-candles	3,875 foot-candles
With black wire screen	38 foot-candles	1,125 foot-candles
Plus window closed	32 foot-candles	865 foot-candles
Plus net window curtain	18 foot-candles	250 foot-candles
Plus awning lowered	7 foot-candles	16 foot-candles

This table is interpreted as follows. A black wire window screen reduces brightness of the light from 90 to 38 foot-candles, while closing the window in addition reduces the effective brightness to 32 foot-candles. Then, with screen and window closed, putting a curtain over the window re-

duces the light to 18 foot-candles. You can interpret the rest of the table with this information.

With the windows bare, the brightness of light on a desk eight feet from the double window was 1½ foot-candles at 10:30 and 3 foot-candles at 1:50. The amount of light in the average living room, with the shades lowered halfway and curtains and drapes over the windows, when no sun shines directly into the room, is less than 2 foot-candles. This is not enough light for any kind of close work or even enough for cooking and ordinary housework.

Our window shades are placed upside down for effective light control. The best light comes from the upper part of the window, yet this is the part of the window we shade first. Window shades should be mounted at the bottom of the window and pulled upward by a cord passing over a pulley.

A window curtain is an inexcusably poor diffuser of light. It does not diffuse well and absorbs from one-fourth to three-fourths of the light. A window of frosted glass would admit 80 per cent of the light and diffuse it satisfactorily. There is no scientific reason for window drapes to exist at all.

The Venetian blind is at present the best device available for controlling light. The slats should be either a natural light color or flat white to reflect light upward to the ceiling of the room. It would be better to place a durable, built-in Venetian blind or shutter outside the window, if means could be devised for controlling it from inside the house. A shutter absorbs heat before it gets inside the house, while a window shade absorbs heat inside the house where it is not wanted in summer. A translucent Venetian blind made of a plastic is now available for interior use.

Where should windows be placed? Windows should be so placed that they throw light evenly into the room and do not cause glare. The ideal location for a window would be in the ceiling. Practically, however, skylights accumulate dirt and are likely to leak during rainstorms or when snow melts. The studio type of lighting, obtained by sloping the ceiling upward toward the north and placing large windows high in the wall, also provides satisfactory light. Diffusing glass assists greatly in spreading light into the room, but this glass has not yet been accepted in many communities.

Glass block diffuses light to a considerable extent. It is more satisfactory for spreading light than is ordinary glass, although it absorbs slightly more light than does window glass. Glass block reflects and absorbs from 15 to 25 per cent of the light when it is kept clean, the amount depending upon the type of finish given the glass.

An advantage of placing windows high in the wall is that space is provided beneath the window for placement of furniture. The ordinary window, placed low in the wall, interferes seriously with proper use of floor space.

If windows are not placed high enough to avoid glare, it is best to have them situated where people who live in the house may sit with their backs toward the windows. The ordinary window is a dangerous cause of eyestrain from glare caused by light reflected from the ground, snow, automobile windshields, and buildings.

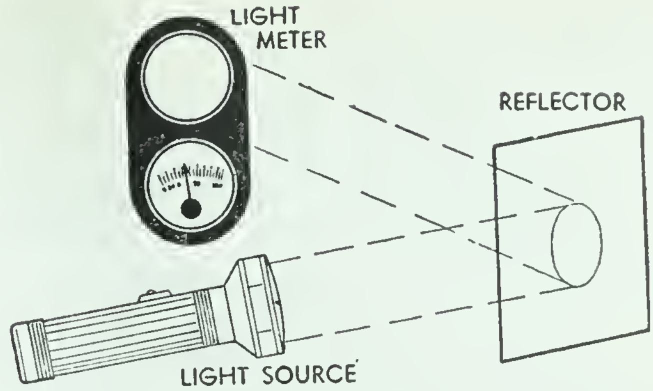
Dormer windows are inefficient, for most of the light is absorbed by the walls of the dormer. Bay windows are no more effective than the same window area placed flat in the walls. The wrap-around window—one placed at a corner—is a novelty and not a great improvement over ordinary windows. If a window is to be used for lighting, it should not be placed to open on a covered porch. There is not enough light available from a porch to justify the cost of the window.

What is the best wall and ceiling color? The importance of using light colors in decorating the house cannot be overemphasized. A room with one window and cream walls and white ceiling is actually lighter than the same room with four windows if the walls and ceiling are painted blue or green. Since windows waste heat and are expensive to install, it is economical to use all the light that can be admitted from a smaller number of windows.

Dark walls increase glare by increasing contrast between the dark parts of the room and the source of light. To face a window in a dark wall produces considerably more eyestrain than to face a window in a cream-colored wall. The amount of color used in interiors should be held to a minimum.

Is artificial lighting now satisfactory? The artificial

lighting of the average home is generally even more inadequate than natural lighting. As explained in the unit on light, artificial light is generally too dim. It is glaring and lacking in uniformity. Colored lamps are too common. Only widespread education of women can bring about better home-lighting.



The ability of different materials to reflect light may be compared by use of this apparatus. A poster may be substituted in a darkened room for the light meter.

Plenty of baseboard outlets are an economy in any house which costs more than $3000.

No unskilled person should ever try to wire a house, for errors in this job might result in burning the house or in the death of one of its occupants.

Demonstration. How Does Color Affect Reflection of Light?

What to use: Projector or beam of sunlight, mirror, boards painted with various colors of flat paint, board painted with aluminum paint, light meter, supports, color wheel, and motor.

What to do: So arrange the projector or beam of light that it falls upon the mirror and is reflected directly upon the poster or light meter. The room should be as completely dark as possible. In front of the mirror place each board to reflect light upon the poster or meter. By comparing two boards at a time, arrange them in order from the one that reflects least light to the one that reflects most.

Set up the color wheel in such a way that you mix various colors with varying amounts of white and black. Rotate the wheel on the motor.

What was observed: List the colors of the boards in order. Can you judge by eyesight whether a given color is light or dark?

What was learned: Apply your observation as a principle to use in lighting houses. Is a tint (color containing white) more suitable than a shade (color containing black) in house decoration?

Exercise. *Complete the following sentences:* A room with 200 square feet of floor area should have a window area of —1— feet,

which is equal to —2— windows, 2½ by 5 feet. The amount of light coming through a black wire screen, at an angle, is about —3—% of the light that comes through a bare window. Light reflected from the floor causes —4—. Ceilings should be —5— in color. Windows should be placed in the upper —6— of the wall. Curtains do not —7— light as well as frosted glass does.

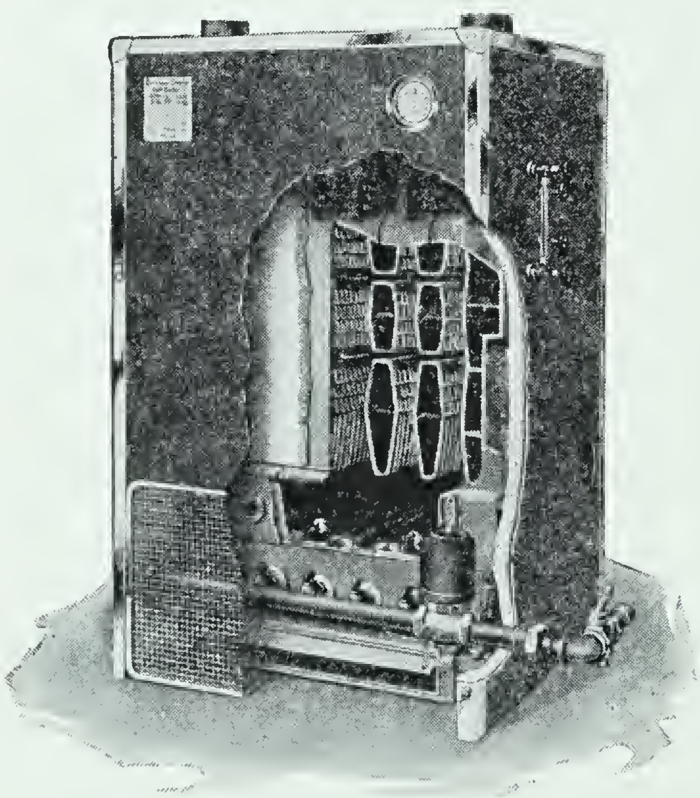
Science activity. Make a study of your home-lighting. Are the curtains properly placed? Plan a better method of lighting your home.

7. What type of furnace should we select?

The selection of a furnace is determined by the amount of money one has to spend, by the cost of fuels in his community, by personal preference as to how the work of firing is done, and by the efficiency of the various types of furnaces. Furnaces may be classified according to the kind of fuels they burn, by the manner in which they are fired, or by their location in the house.

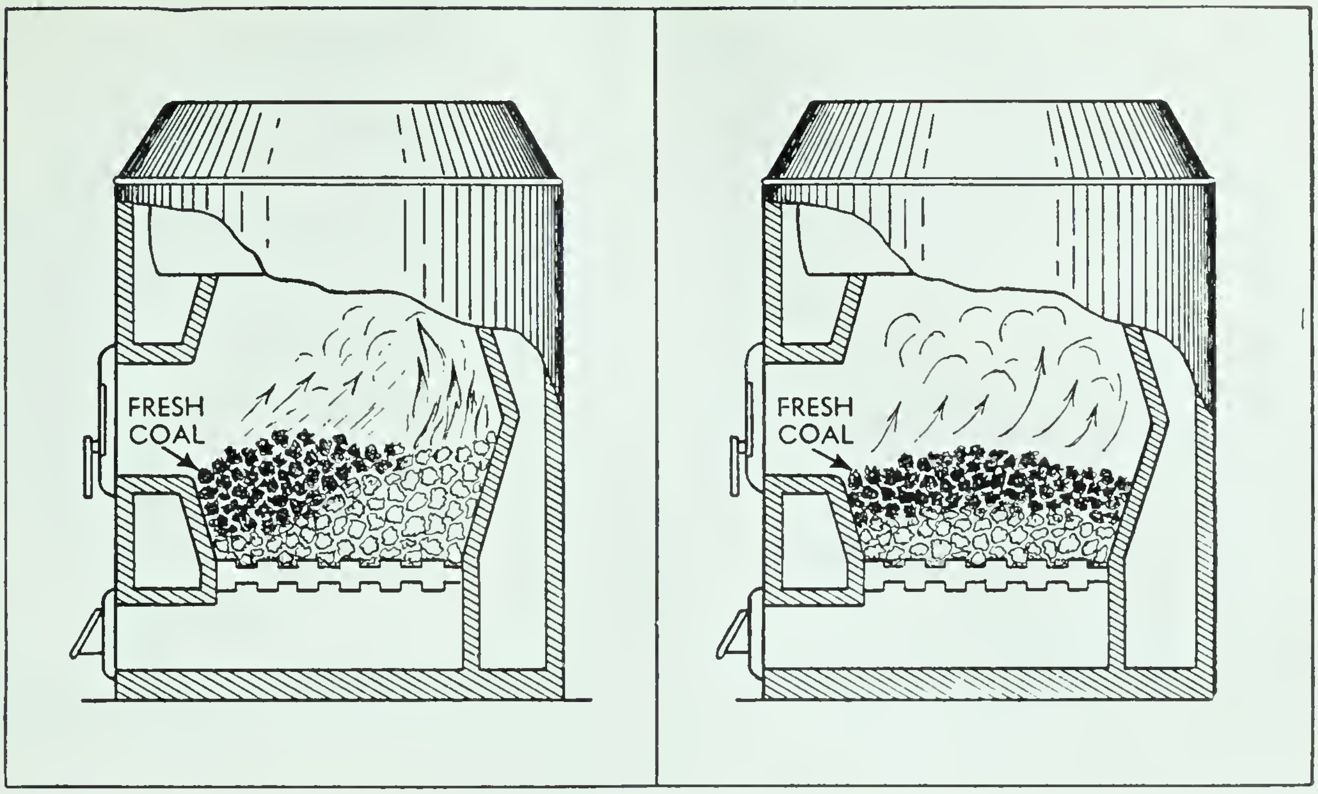
Why is a stove used? In most houses which cost less than $3000 a stove is the standard heating system. Stoves are used in somewhat more expensive houses in the South than in the North, because in the South heating is required for a smaller part of the year and a furnace is not so essential. When the cold season ends, the stove is removed from the house. Stoves may burn wood, coal, fuel oil, or gas.

The chief advantage of a stove is its low cost. The disadvantages are numerous. Fuel with its attendant dirt must be brought into the living room. Smoke blackens the walls and ceiling. Heat distribu-



Courtesy The Burnham Boiler Corp.

An essential factor in heating water is to expose a large area of pipe to the flame. A properly constructed gas-heated boiler is highly efficient.



In the correctly fired furnace (*left*), smoke from the fresh coal is burned by flames from the hot coal in the back of the furnace. Incorrect firing (*right*) smothers the hot coals and permits unburned gases to escape through the chimney.

tion is generally poor, as only one room is heated by each stove. Most stoves are unsightly in the room.

The circulating heater is somewhat better than an ordinary stove, for it has a metal jacket so placed that hot air flows upward by convection between the jacket and the stove. Thus heat is better distributed, for there is no unpleasantly hot, direct radiation from the stove. Coldness of floors is decreased by circulation of hot air in the room.

Why is the coal furnace used? A furnace is a stove which is used to heat air or water to circulate heat through a building. It is usually made of cast iron but sometimes of firebrick or other materials. The bottom of the furnace is a series of bars called a grate, through which air flows and through which ashes fall. There is a draft door below the grate, a fuel door above the grate, and a stovepipe outlet. There is usually a damper in the stovepipe.

The coal furnace may be fired by hand or by a stoker. When it is fired by hand, the fire is kindled in the usual way, the drafts are set, and coal is added as needed. As coal burns down, a clinker is formed which must be broken up

from time to time. Ashes are shaken into the ash pit and must be removed.

When fresh coal is added, it is best to push the hot coals to the back of the furnace and add the fresh coal in front. If coal is added to the top of the fire, it is distilled—that is, gases are driven off which escape up the chimney without being burned. Not only does their loss represent waste of fuel, but the smoke formed is a menace to health and cleanliness. If coal is added in the front of the furnace, the gases pass above the hot coals in the back and are raised to their kindling point.

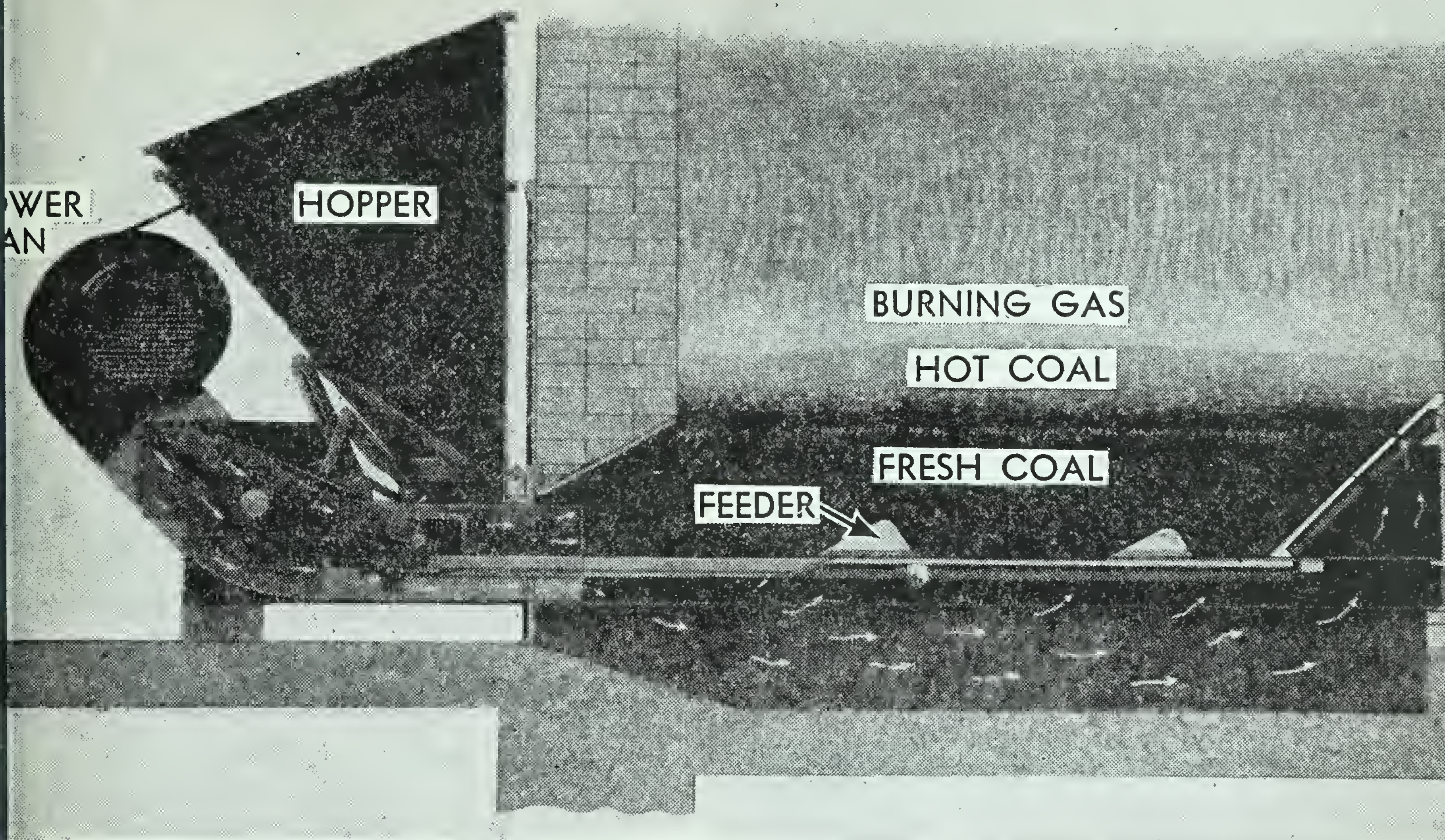
The coal stoker is a machine that feeds coal into the furnace automatically. The coal is usually driven into the firebox from below. Little coal is wasted, because gases flow upward through the fire and are burned. A stoker usually saves enough coal in a period of 10 years to pay for the cost of installing it. Most stokers are used in connection with forced draft—that is, air is blown through the fire by a fan. To the cost of coal the user of a stoker must add the cost of electricity used to operate the stoker.

What are the advantages of oil burners? The oil burner is similar to the coal furnace. The draft door is left closed, or none is built in the furnace. The oil burner includes an oil pump which sprays oil into the furnace, a fan which provides a strong draft of air, and a pilot light or electric device to keep the oil ignited.

It is possible to illustrate the principle of the oil burner with very simple apparatus. If kerosene is sprayed from an atomizer over a candle flame, the kerosene burns with a wide, hot, clean flame. (*Do not attempt this experiment. It is dangerous!*) If the kerosene is poured into a dish and ignited, it burns with a sooty, yellow flame. The oil burner, like the atomizer, mixes oil with air. The fuel used is a low-grade petroleum oil.

The chief advantage of the oil burner is the small amount of attention it requires. If the furnace is in good condition and the fuel tank is kept filled, it needs no attention. There are no ashes to remove, and there is little soot or dirt from it.

What are the advantages of the gas burner? The gas burner is similar to the oil burner in convenience and is



Courtesy Detroit Stoker Company

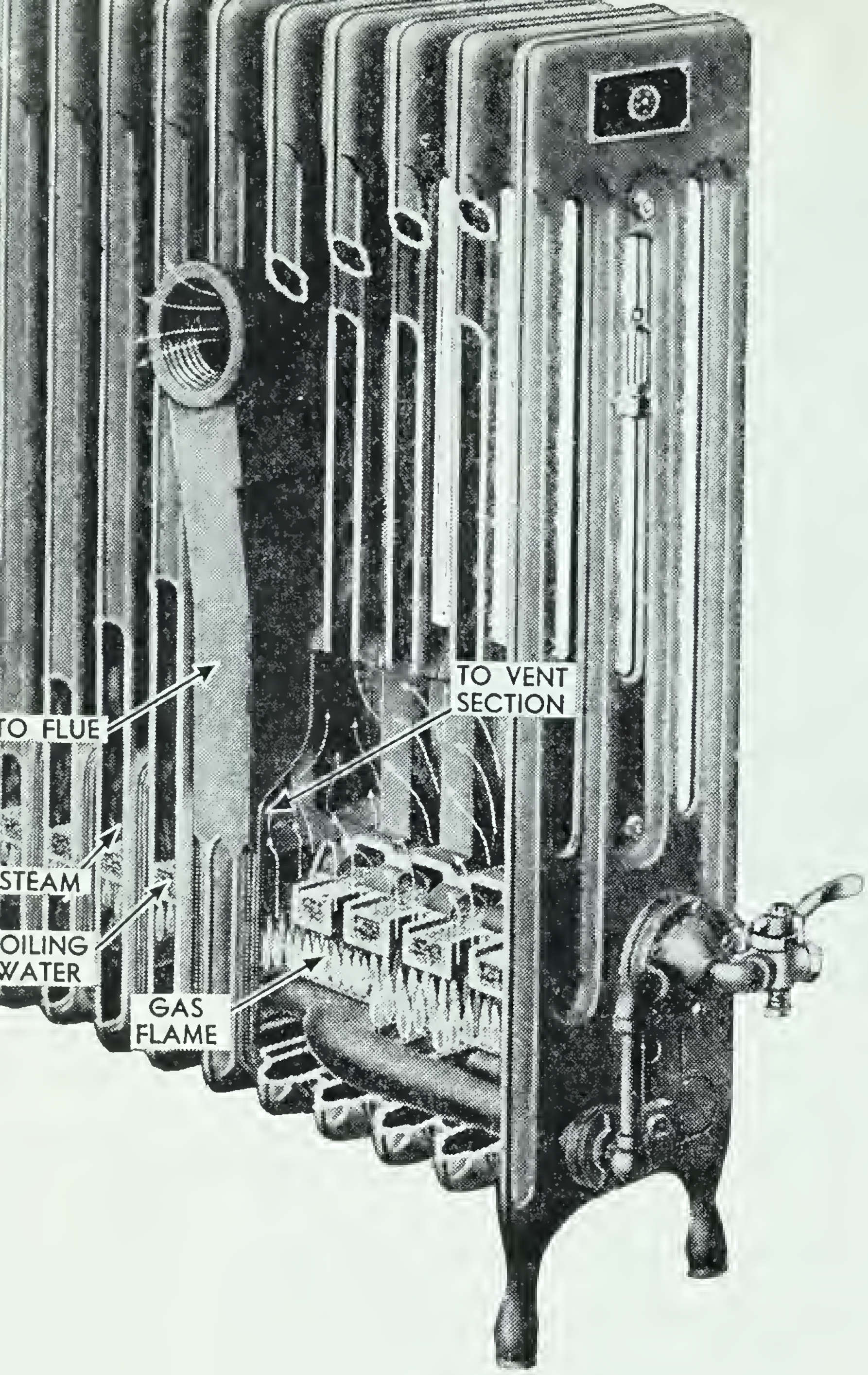
Coal is fed from the hopper and forced beneath the fire by the machinery of the stoker. Air is forced through the fire by the blower. This apartment-sized stoker-fired furnace is highly efficient.

simpler in operation than any other furnace. It is essentially a huge Bunsen burner, in which gas and air are mixed and burned cleanly. The gas burner may be installed in any furnace but is most efficient in a furnace built especially for use with gas.

There are a number of ingenious gas stoves on the market. One kind looks like a radiator, and actually is one—that is, water is heated in the radiator by a gas flame underneath it. Another kind is set into the floor and circulates hot air in the room.

Gas always presents hazards not risked with other fuels. A broken connection or accidental putting out of the flame may result in violent explosion, poisoning, and sudden death. Gas burners must always be connected to a flue. In fact it is unsafe to use any flame-producing heating device without a flue.

Why is the fireplace undesirable? The fireplace is so inefficient that it has no merit as a heating device. Its use is purely decorative and sentimental. A fireplace is included



Courtesy James B. Clow and Sons

This unusual heating device is both a furnace and a radiator. The gas flames heat water in the bottom of the radiator, while burned gases are carried to a flue connection. The steam thus created heats the radiator.

in modern homes because of a traditional pleasure obtained from watching an open flame.

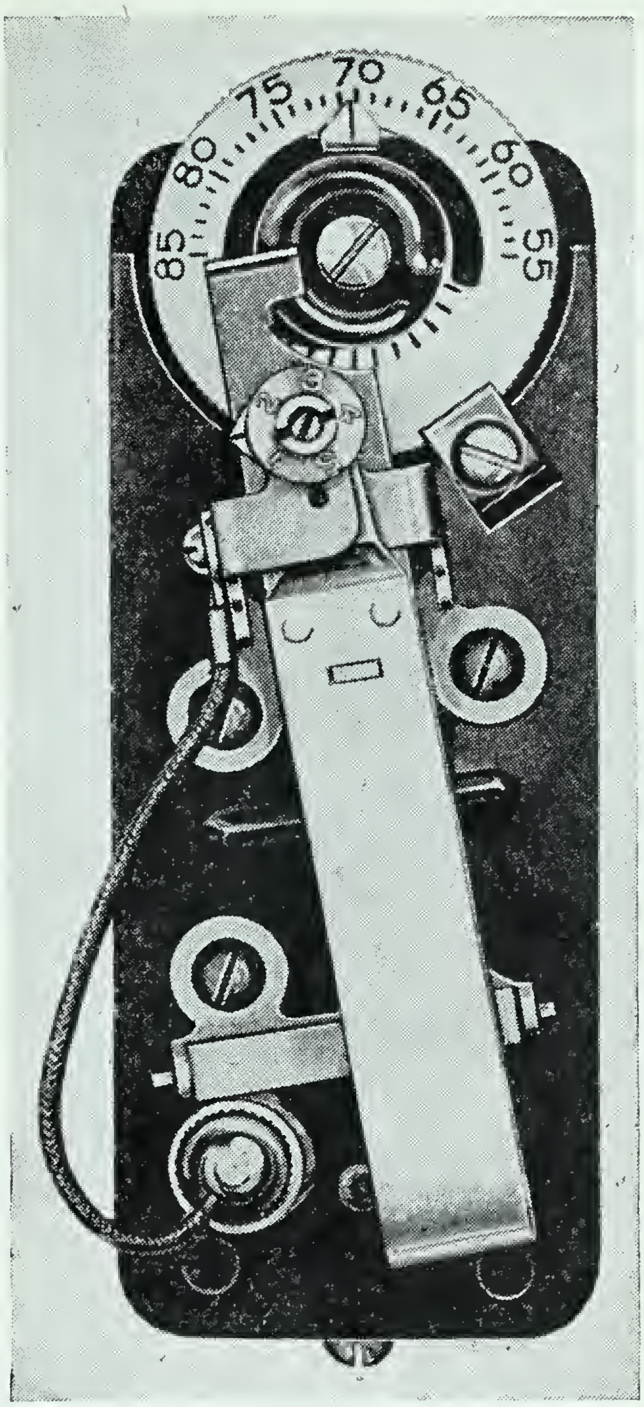
How does efficiency of various types of heating plants compare? The efficiency of a heating plant is determined by dividing the number of British Thermal Units liberated from the furnace by the total number of B.T.U. in the fuel. The most efficient of all heaters is the electric radiation coil, which delivers almost 100 per cent of its energy into the room. Gas burners are next in efficiency, ranging from 75 to 80 per cent for burners operated properly. Efficiency of gas burners may be as low as 30 per cent when poorly adapted to the furnace in which they are used.

Oil burners range from 60 to 70 per cent in efficiency. Most coal furnaces which are operated by stokers are about 50 to 60 per cent efficient. Hand-fired furnaces range from 25 to 50 per cent efficient. The fireplace is 5 to 10 per cent efficient.

Electricity provides the most expensive heat one can buy in most cities, the average cost amounting to eight times that of coal. Manufactured gas is expensive—costing more than enough to offset its efficiency. Oil is considerably more expensive than coal as a fuel.

Probably the cheapest heat over a period of years is obtained by using soft coal in a stoker-fired furnace. This cost

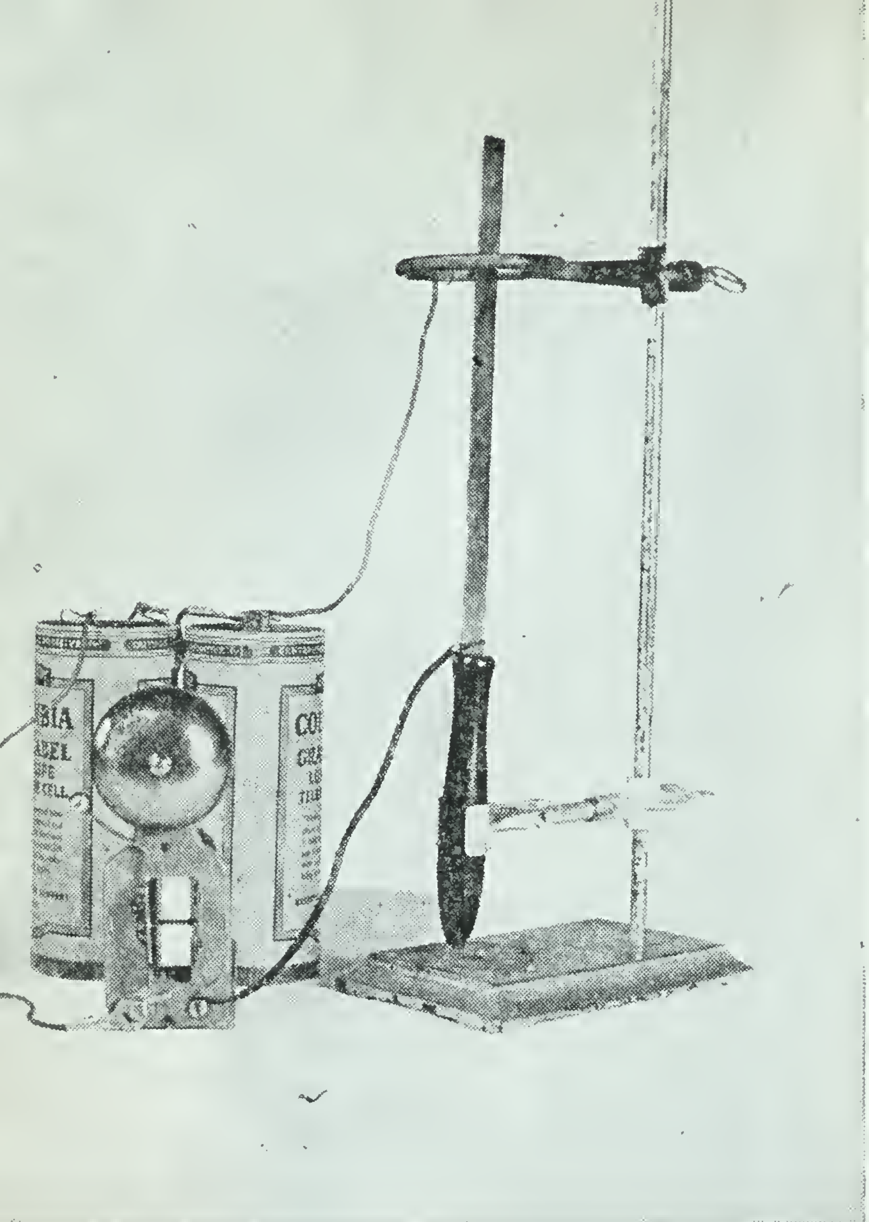
does not include cost of labor for attending the furnace. It is impossible to set a standard rule for the entire United States, for freight costs and abundance or scarcity of a given kind of fuel is an important factor in cost.



Courtesy Minneapolis Honeywell

The thermostat consists of a metal strip, which expands and contracts with the temperature changes, and of accurate controls for regulating the furnace. This thermostat is set to maintain a temperature of 70°.

What is a thermostat? The oil burner, the coal stoker, and the gas burner may be automatically controlled by use of a thermostat [thûr′-mȯ·stăt]. A thermostat is essentially a metal bar—made of a strip of brass and a strip of iron welded together—which bends as it is heated or cooled. When the bar is cooled, it bends toward the iron; and when it is heated, it bends toward the brass, because of the greater change in brass when it expands. This bar is usually so coiled or bent that it takes up little space. The moving bar may be used to make electrical contacts to turn on the fire when the room is cooled and to shut it off when the room is warm. An accurate thermostat will maintain a temperature range of less than 2 degrees. It may be set at any desired temperature. Many thermostats have clock arrangements. After a certain hour, heat is turned off in the evening and turned on in the morning. The thermostat controls the motors which control the fires. Thus the operation of the heating plant becomes so nearly automatic that it requires little attention.



This demonstration apparatus is used to show the principle of the thermostat.

DEMONSTRATION. WHAT IS THE PRINCIPLE OF THE THERMOSTAT?

What to use: Compound bar, ring stand, clamp, ring, doorbell, dry cells, wire, burner.

What to do: Arrange the apparatus as shown in the illustration. Wrap the wire from the bell around the blade of the compound bar to make a good connection. Wrap the wire from the dry cell around the ring in such a position that when the blade is bent it will touch the wire. Heat the compound bar with the burner flame.

What was observed: How does the heat cause the bell to ring?

What was learned: What is the principle of the thermostat?

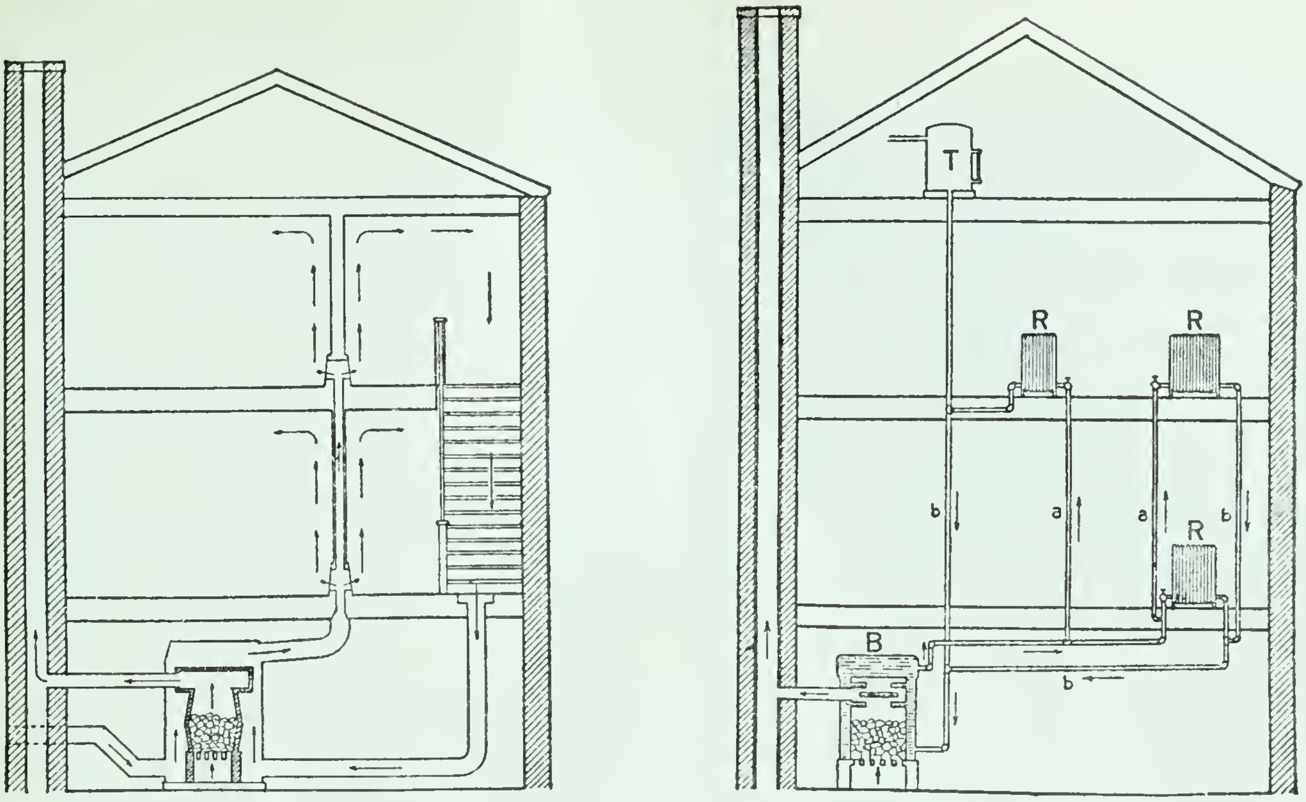
Exercise. *Make a table by ruling your paper into five columns. Head the columns as follows:* TYPE OF HEATING DEVICE, KIND OF FUEL, HOW FIRED, EFFICIENCY, RELATIVE COST. *Find the types of heating devices listed in the text. Use these words to fill in the other columns:* oil, wood, coal, gas, hand, stoker, gas and air pressure, pump, burner, costly, cheap, fairly costly. *Find the list of efficiencies in the book. You may use words not in this list if you wish.*

Science activities. 1) Learn exactly how your own heating plant works and compare it with a different type of plant.

2) Make a model thermostat. You can make a compound bar if you can rivet strips of the two metals together.

8. How is heat distributed within the house?

Liberating heat from fuel is not the only problem connected with house-heating. It is necessary to carry the heat from the furnace and to distribute it where it is needed.



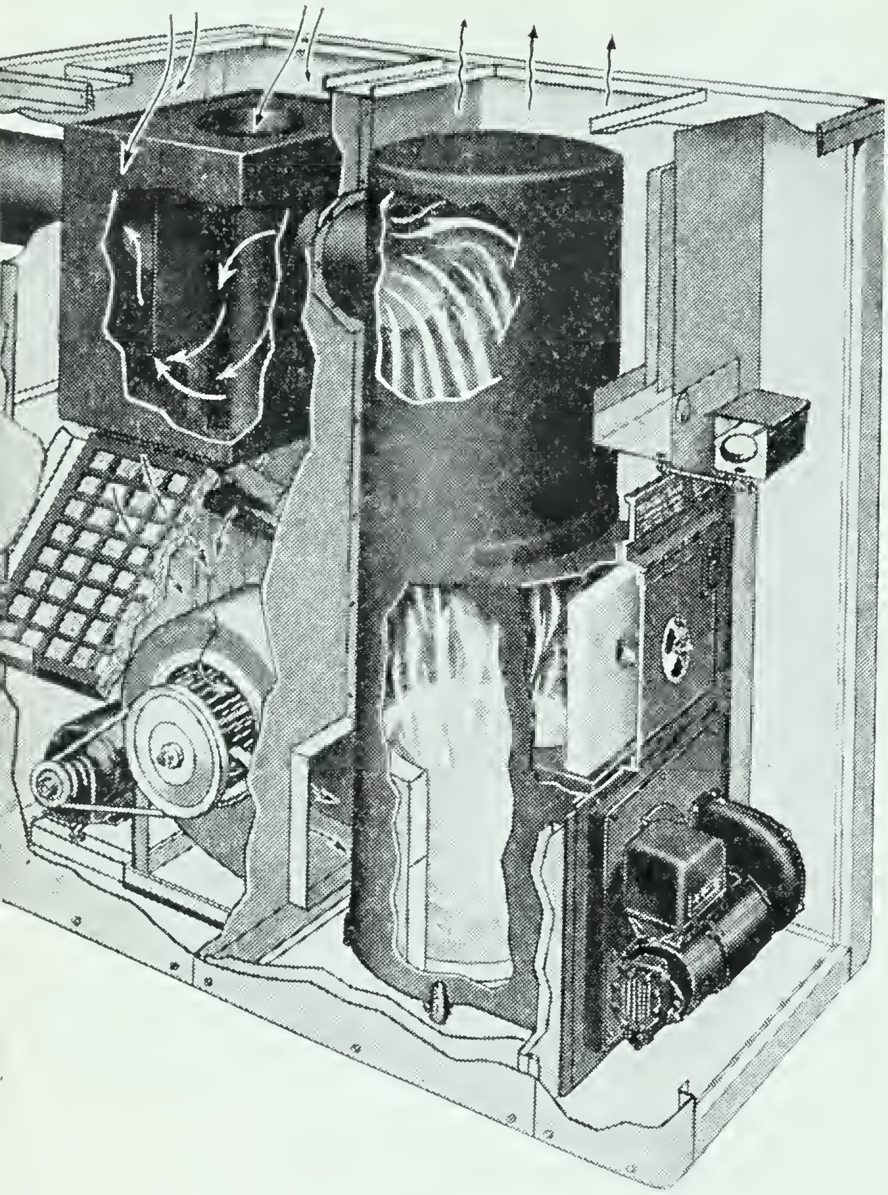
Both hot-air (*left*) and hot-water heating systems operate because of convection currents. Why is there an overflow tank on the hot-water system? What action takes place at **a** and **b**? What is **R**? **T**? **B**?

There are three carriers of heat in common use: steam, water, and air.

How does the hot-air system work? Air moves in the hot-air heating system by convection. Since air expands as it is heated, its weight per unit of volume is reduced. The cold air settles, and the warm air rises.

The hot-air furnace is usually located in the basement. Air flows upward into the rooms through large, sheet-metal pipes. There may be one pipe opening directly into the room above the furnace, or there may be pipes leading to and from each room. In the one-pipe, or so-called "pipeless," furnace return air flows down a pipe surrounding the hot-air pipe. In the piped furnace, hot-air pipes carry air from above the furnace to the rooms; the cold-air pipes return it to the bottom of the furnace. Air is thus recirculated many times, because it is not economical to lose the heat immediately. Some fresh air is mixed into the recirculated air through a pipe from out of doors.

If a fan is used to speed up the circulation of air, the system is said to provide forced circulation. If differences in temperature move the air, the system is called a gravity system.



Courtesy Round Oak Company

On the right is an oil-burning furnace. On the left is a radiator, filter, and fan. The black arrows show the circulation of air from the room, around the furnace, and back into the room. White arrows represent burning gases.

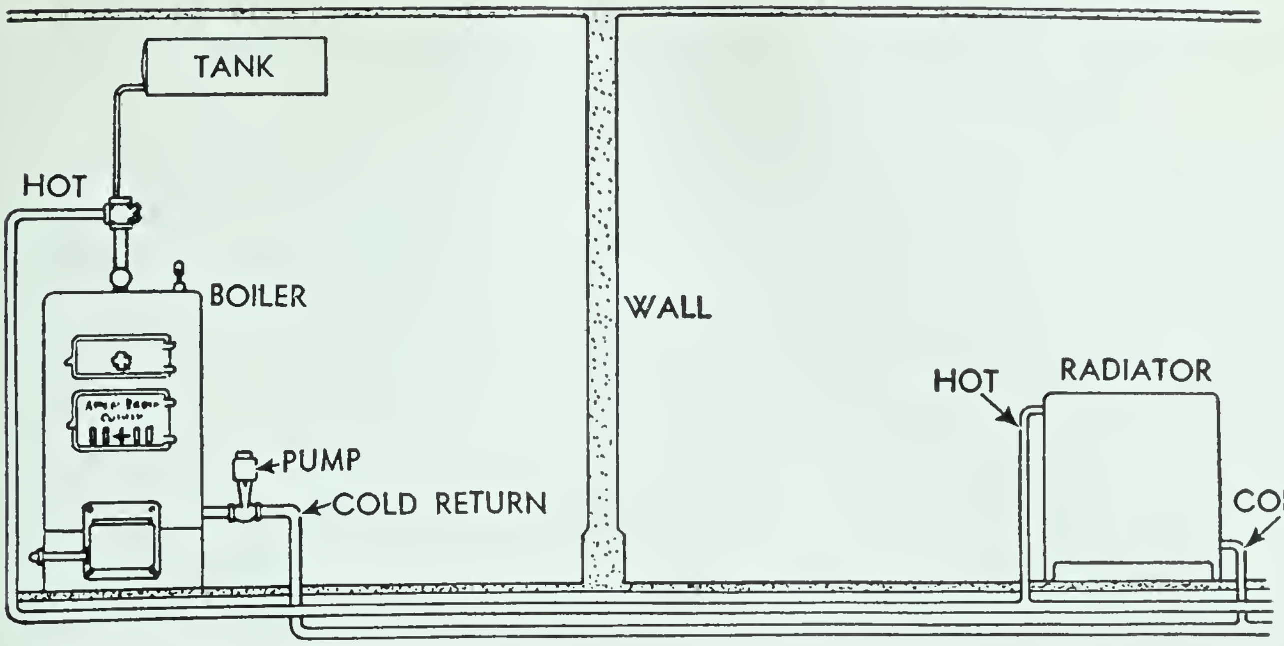
The hot-air system is limited in its usefulness. It should be used only in houses of four to eight rooms. Hot air tends to carry soot and dust from the basement to the living space.

How does the hot-water system work? A hot-water heating system is equipped with a boiler which in small systems surrounds the furnace. The large boiler may be equipped with fire tubes or with water tubes. Hot water circulates by convection, just as hot air does, but is carried by pipes to radiators within the rooms. The cooled water returns to the boiler in another set of pipes. Cold water flows into the boiler at the bottom, and hot water leaves the boiler from the top. Hot-water systems usually are provided with an expansion tank in the attic or an overflow pipe through the roof. This is done so that when the water expands, it can escape without bursting the pipes.

Because water holds heat well, the temperature of the radiator is kept fairly even. This is an advantage in maintaining even temperatures but a handicap in obtaining rapid heating. Heat is released into the room only as the water cools.

Hot-water systems are generally used in houses of 6 to 12 rooms. The hot-water system heats different rooms more evenly than does the hot-air system.

How does the steam system work? The steam system operates on a different principle from that of the hot-air and



Courtesy American Radiator Company

By using a pump, it is possible to put a hot-water radiator on the same floor as the boiler. Note the overflow tank and the location of the pipes.

hot-water systems. The steam system depends upon the pressure exerted by the steam in the boiler to provide movement of the hot gas, and upon a change in the state of matter to release heat. Since heat is required to change water to steam, the heat stored in the steam is given off in the radiator when the steam changes back to water. The warming of the room thus depends upon the condensing of the steam. The hot water formed by the steam gives off heat too.

Steam is generated in a boiler provided with a steam dome in which the steam collects. On this dome are a pressure gauge and a safety valve.

Steam may be carried in a one-pipe system, a two-pipe system, or a two-pipe vapor system. In the one-pipe system, steam flows upward through the pipe to the radiator. The steam condenses, and the water formed trickles down the sides of the radiator, along the bottom, and down the sides of the steam pipe to the boiler. In this system, steam enters the bottom of the radiator.

In the two-pipe system, the steam enters one end of the radiator, and the water flows from the radiator at the other end. The steam enters at a point high enough that condensed water will not cover the pipe.

In the vapor system, the two-pipe arrangement is used, and in addition a pump reduces the pressure in the return pipe,

Courtesy Coleman Lamp and Stove Company

A small gas stove is located inside this floor register. Air circulates through the grating. Why must all gas stoves have flues?

causing steam to flow more readily through the system. The condensed water is forced against pressure into the boiler by the pump.

The steam system of heating is used in all large buildings and in many homes. It is superior to hot water for rapid heating, for the radiators may be made hotter. It is efficient. The vapor system is particularly efficient for use in large buildings.

Steam systems, like hot-water systems, are fairly expensive to install.

How do radiators give off heat? Three factors determine the effectiveness of the radiator. The first of these is temperature. When heat is radiated from one object to another, the rate at which the heat is radiated is in proportion to the difference in temperature. Heat is given off about twice as fast from a radiator at 170 degrees as from one at 120 degrees.

The second factor which determines how much heat is radiated is the amount of radiating surface. If two radiators are of the same temperature and one is twice as big as the

other, the bigger one gives off twice as much heat as the smaller.

Because hot water rarely reaches the radiator at 212 degrees, hot-water radiators must be made considerably larger than steam radiators. The larger size of the hot-water radiator is a disadvantage, both in original cost and in space occupied in the room.

The third factor in heat radiation is color and type of radiating surface. A rough, black surface is the ideal radiator, and a smooth, polished surface the poorest radiator. A good reflector is a poor radiator. The practice of painting radiators with aluminum paint decreases their effectiveness.

Air should move freely through the radiator, for air can carry heat into the room by conduction and convection. Do not cover radiators in any way.

Steam radiators are equipped with valves to permit air to escape. The valve is essentially a hole into which a needle fits. The needle is pushed tightly into the hole when a piece of metal in the valve is warmed enough to expand. The valve is so constructed that condensed steam drains from it into the radiator.

Demonstration. Does Steam Hold More Heat Than Hot Water Does?

What to use: Two 400 cc beakers, flask, thermometer, balance, stopper, glass and rubber tubing, burner, ring stand.

What to do: Place two beakers on the balance, and put equal amounts of cold water in each, filling them about half full. Record the temperature. Remove one beaker from the balance, and run steam into it. Steam is produced by boiling water in the flask, which is equipped with a delivery tube in a one-hole stopper. Let steam run through the delivery tube until it is hot before putting it into the beaker. Let steam run into the beaker for about five minutes.

Remove the tube from the beaker, and return it to the balance. Pour enough boiling water into the other beaker to make them balance.

What was observed: Record temperatures and find the change in temperature in each beaker.

What was learned: Does steam carry more heat than an equal weight of hot water? Why?

Exercise. *Complete the following sentences:* The movement of air and water in heating systems is a form of —1— currents. Steam gives off its heat when it —2—. Movement of steam, water, and air depends upon the energy possessed by —3—. The greatest amount of air movement and ventilation is provided by the —4— system. The evenest temperatures are provided by the —5— system. The —6— system is used for a 60-room building. The rate of radiation from one surface to another is in proportion to the —7— in temperature. The amount of —8— determines the rate of radiation. The best surface is rough and —9— in color. Air valves are provided on —10— radiators.

Science activity. Study the school heating plant, learning especially how the heat is carried into the rooms.

9. How do we maintain good air conditions?

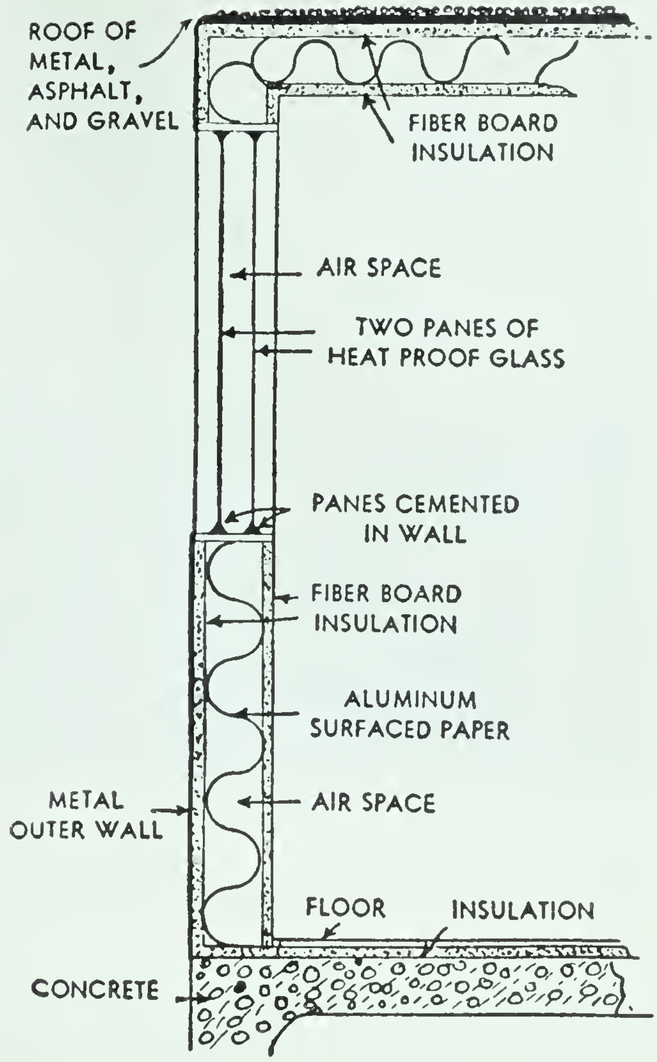
The condition of the air in the house has much to do with our comfort and vitality. It is possible that the condition of the air may actually make an important difference in health. A good condition of the air includes a comfortable temperature, correct humidity, a reasonable amount of air movement, and freedom from unpleasant odors, bacteria, dust, and pollen.

What is the best temperature for health? There is no one temperature that is correct for house-heating, despite claims to the contrary. The amount of activity of the occupants of the house is one factor in determining the need for warmth. Humidity makes a difference in the feel of air, the moister air on the average feeling warmer than dry air. The temperature of surrounding surfaces makes a great difference in the need for warmth, for if one radiates heat to a cold surface, he feels cold, even though the air may be warm. An icy window increases the need for heat in the room.

The season of the year and amount of clothing worn are factors in determining desirable temperature. In winter clothing, one may be comfortable at 68 degrees, and in summer clothing, at 75 or 80 degrees. In summer there should not be too great a difference between indoor and outdoor temperatures. Then too, some rooms require more warmth than do others. The bathroom should be warmer than the kitchen. Age, sex, and the vitality of the people who live in

the house are other factors. A healthy young man dressed in a wool suit and playing table tennis needs much less heat than does his grandfather, sitting in his shirt sleeves and reading.

Generally a temperature of 72 is considered comfortable in winter, and a temperature of 75 satisfactory in summer. The problem of maintaining comfortable temperatures would be simplified and the cost of air conditioning would be reduced if women would wear more clothing in winter and men would wear less clothing in summer.



There are many methods of insulating walls. A few are shown in this diagram. Of course, only one type would be used in one wall.

What is the best humidity? Humidity of the air is measured in two ways. Absolute humidity is the amount of water vapor by weight in a given amount of air. Relative humidity is the amount of water vapor in the air at any given time, compared with the amount of water vapor the air would hold if saturated at the given temperature. Relative humidity is expressed in per cent. A relative humidity of 100 means that water vapor is ready to start condensing, for the air holds all the vapor it can. A relative humidity of 50 indicates that the air could absorb an amount of water equal to the amount of water vapor already in the air. A relative humidity of 0, of course, would indicate that the air is absolutely dry.

When the temperature of the air increases 20 degrees, its ability to hold water vapor is approximately doubled. If air at 50 degrees has a relative humidity of 60 and the air is heated to 70 degrees, the relative humidity drops to 30, although no water is taken from the air.

Courtesy The Celotex Corporation

Adequate insulation is essential for successful air conditioning. A fiberboard wall is a good insulator.

A relative humidity which is too high in the summer causes extreme lack of vitality. Perspiration clings to the body. When the humidity is too low, the throat feels dry and the skin is uncomfortable.

Much information appearing in print about need for high humidity in winter seems to be inspired by those who sell humidifying equipment. If the house is too humid, water condenses on the windows, in the walls, and in the attic. The moisture causes decay and decreases the effectiveness of insulation. A wet blanket is a poor cover for a person or a house. It seems that a relative humidity of 30 is enough for winter. It is cheaper to heat the house to overcome the feeling of coldness caused by dry air than it is to evaporate enough water to increase the humidity.

If air is cooled in summer by blowing it through refrigerating coils or pipes carrying cold water, water vapor must be removed from it. To make air at 75 degrees dry enough for comfort, the air must have been cooled to about 50 degrees to condense the water vapor. The greatest expense in cooling air is the removal of excess moisture.

How do we measure humidity? There are on the market

two types of devices which measure humidity. One employs a strand of hair kept tight by a spring. The hair expands and contracts with moisture changes, and operates a needle which moves across a marked dial. This type of hygrometer is relatively inaccurate. The other type of measuring device employs a wet-and-dry-bulb thermometer. The wick around the end of the wet bulb is kept moist and is cooled by evaporation. The drier the air, the more rapid the evaporation and the lower the temperature of the wet bulb. This device is read by the use of tables.

What is ventilation? Ventilation includes the movement of air and the exchange of air between indoors and outdoors. There are three kinds of ventilation.

Gravity ventilation is obtained by opening a window at the top and bottom. It works only when the temperature indoors is different from that outdoors. The chief objections to gravity ventilation are that it produces cold floors in winter and does not work in summer.

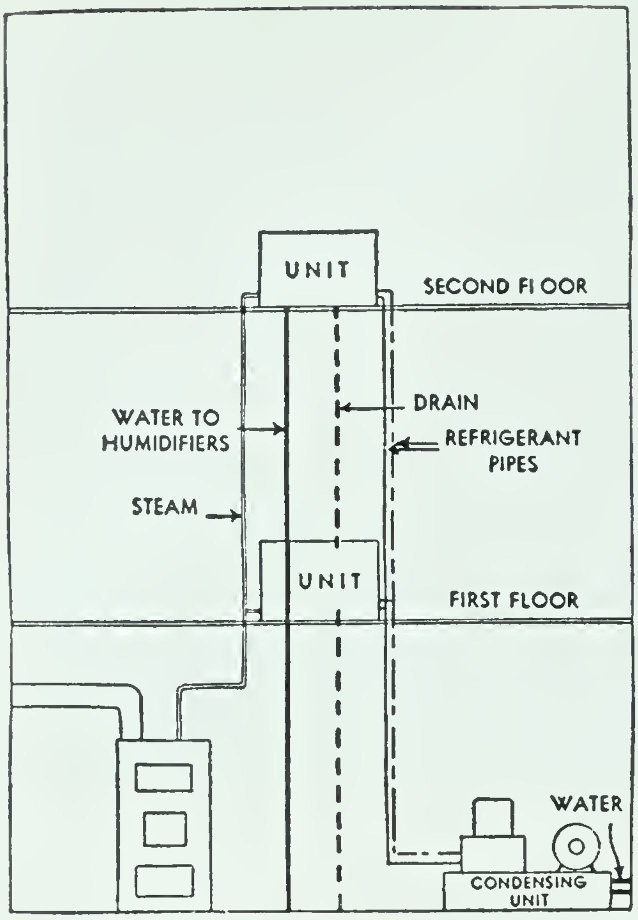
Cross ventilation is dependent upon the wind blowing. When windows are opened on opposite sides of a room, the wind blows through and removes the stale air from the room. This method of ventilation also produces cold floors in winter and may cause drafts much too strong for comfort.

Window ventilation seems to be as good for the health as forced ventilation, if comfort is not considered an important factor. Many people refuse to leave out comfort as a factor, however. Windows that are well placed for ventilation are poorly placed for light.

Forced ventilation is produced by using fans. An ordinary electric fan may be used to circulate air in the room or to blow stale air out the window. In winter a fan turned on a hot radiator or stove will relieve coldness of floors and will cause the hot air that accumulates near the ceiling to move down where it can be enjoyed.

There are many systems of forced ventilation, but all depend upon use of either the common vane-type fan or the cylinder-shaped fan. Some schools have unit ventilators in the schoolroom; others have air provided from a central system.

What is air conditioning? Air conditioning provides con-



Of the many systems of air conditioning, this is one of the commoner. Trace the movement of heat from the rooms, through the machine, and out through the water pipes. Compare this with the electric refrigerator.

trol of temperature, humidity, circulation, and cleanliness of the air. It includes both heating and cooling air as required.

Many so-called air conditioners are merely hot-air furnaces equipped with a fan and an inefficient humidifier.

Air may be humidified by spraying water through a current of air or by heating water in an open tank. Rate of evaporation depends upon the amount of surface, the temperature, and the rate of air movement. When water evaporates, either from the air of the room or from the furnace tank, a certain number of calories of heat are required to evaporate a given amount of water. Evaporating water in the room cools it.

Water vapor may be condensed from air by circulating the air over cold pipes.

Air may be cleaned by forcing it through wet cloths, through sprays, or through filters. Filters are frequently made of glass wool, moistened with mineral oil. A good filtering system removes from the air more than 90 per cent of such solids as dust and pollen.

Odors are difficult to remove from air. Tobacco odors increase in unpleasantness as the smoke becomes stale for a period of three or four hours. About the only way to remove such odors from the room is to remove the air, replace it, and condition the fresh air as it enters the house.

Before air conditioning can be practical, the house must be well insulated and the walls must be moisture-proofed so that the humidity will not rot the timbers or cause insulation to settle. Windows and doors must be tightly fitted. Most houses

cannot be air conditioned except at too high a cost. Air conditioning is now a luxury in the small home. It is an important aid to sales in stores and restaurants, however.

DEMONSTRATION. HOW DO WE MEASURE HUMIDITY?

What to use: Wet-and-dry-bulb thermometer with tables on cylinder, hair hygrometer.

What to do: Operate the devices for measuring humidity according to directions supplied by the manufacturer.

What was observed: What is the relative humidity of the room?

What was learned: State briefly the principles upon which humidity is measured.

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* temperature, relative humidity, humidity, water vapor, summer temperature, winter temperature, air movement, cross, gravity, forced, air conditioning, filter, condensation, insulation.

Science activities. 1) Arrange with the owner of a business equipped with air-conditioning equipment to allow you to observe how the machinery operates. Where does the heat go when it leaves the room?

2) Using thermometers from advertising matter, make a wet-and-dry-bulb thermometer. Look up tables to accompany it in reference books.

10. How is safe plumbing installed in the house?

When water is distributed in the house and wastes removed, we rarely think of the complex system of pipes and equipment necessary to permit us to get along with so little effort. Yet a child who lives where water must be drawn from a well, carried in a pail, and used with care to avoid causing extra work can hardly understand how water can be used as lavishly as is common in our cities.

Not many more than half the houses in the United States are equipped with any sort of plumbing at all.

What is plumbing? Plumbing is the entire system of pipes which carry water within the house. It includes the hot-water system, the water pipes, the sewerage pipes, and connections to the water main and sewer. In some farm homes it includes a pump and a water tank. Some houses have water softeners

or cisterns for rain water. The word "plumbing" is also used loosely to apply to plumbing fixtures, the washbowl, the tub, the sink, the flush tank, and the laundry equipment.

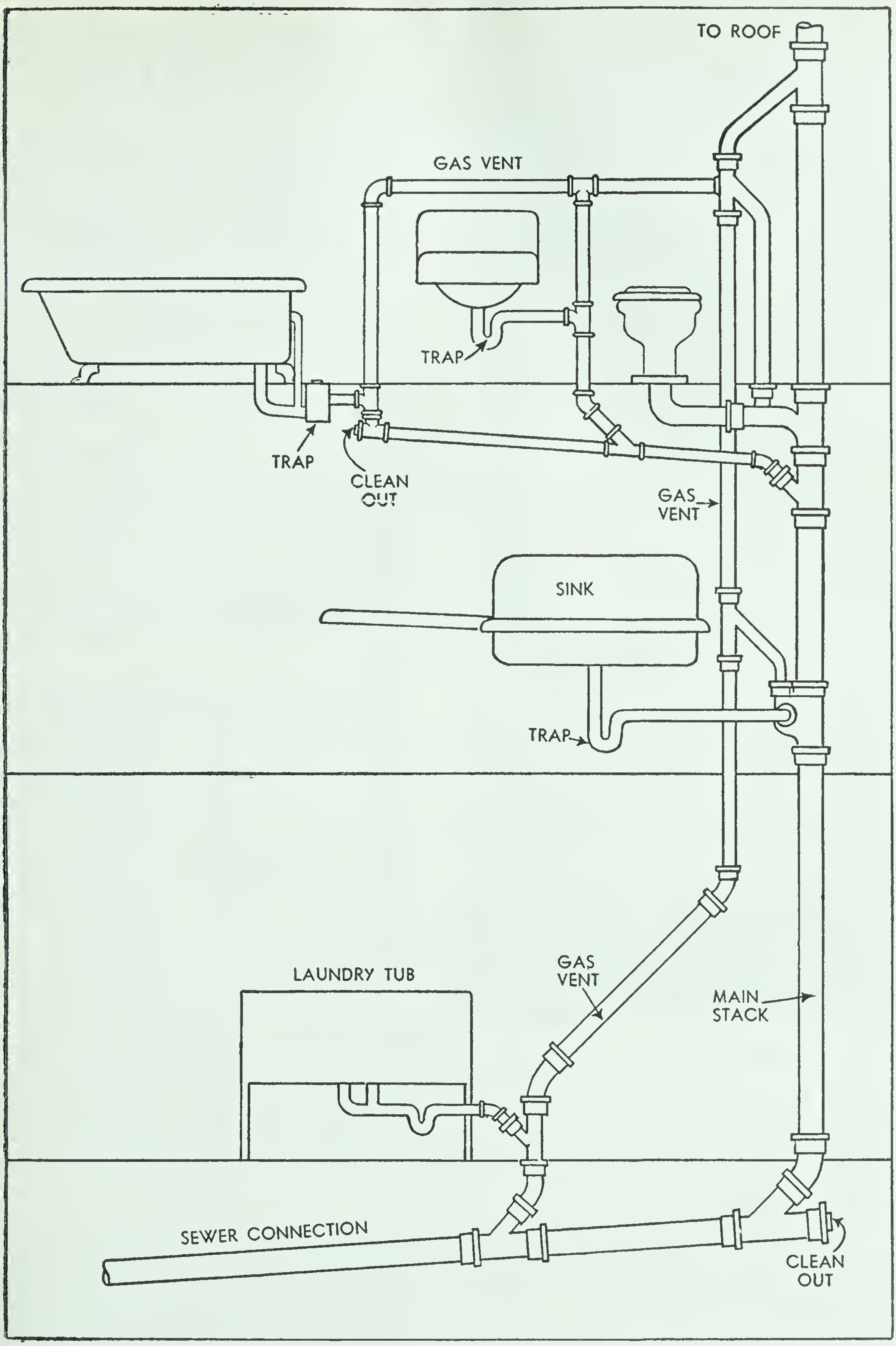
What are the general rules to observe in installing plumbing? The first and by far the most important rule to observe in installing plumbing is to make it absolutely safe from the health standpoint. All possible connections between sewers and the water supply must be avoided.

It is possible that a connection between the toilet and the water supply may occur. One state health department has an unpleasant but definitely educational demonstration set up in such a way that it can be carried about the state. On a platform at the height of the second story is a toilet bowl filled with colored water. On a lower platform is a drinking fountain. The flush pipe is of the type connected directly to the city water and not to the usual flush tank. The water pressure is then shut off and, as a result, a slight decrease in air pressure is produced in the pipes. When the fountain is turned on, colored water from the toilet bowl runs from it. It may be unpleasant to contemplate such demonstrations and less pleasant to see them, but if the amount of cholera, typhoid, dysentery, and other water-carried diseases can be cut down, the result is worth the unpleasantness.

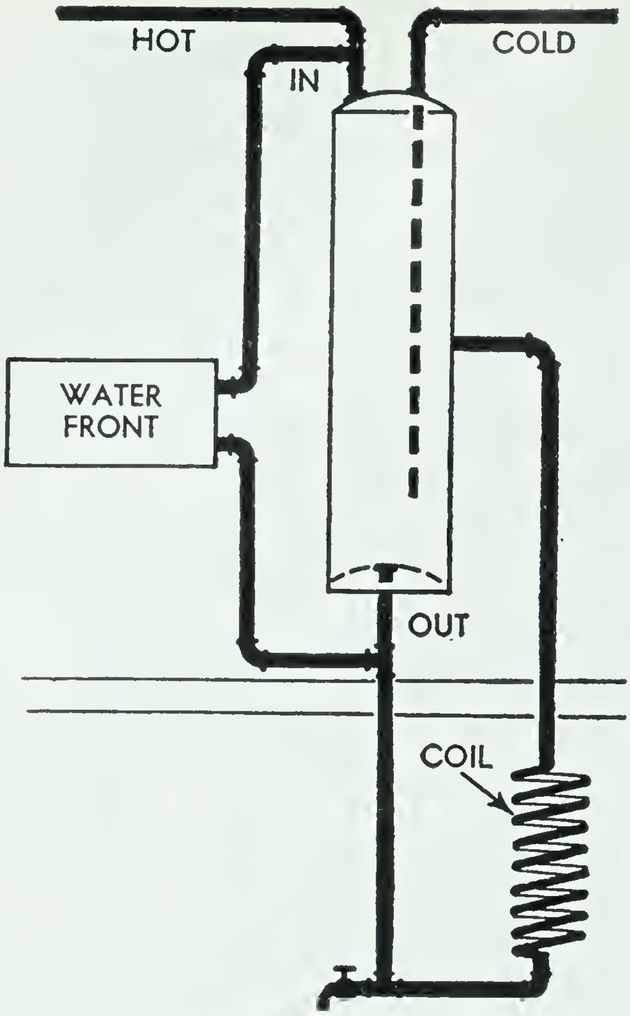
The only safe type of toilet flush tank is one into which water runs from a pipe completely *above* the water level in the tank. The supply pipe must not pass up through the water in the tank.

The ends of faucets should be well above the water in the washbowl even when the bowl is full enough to spill over on the floor. Water may be sucked up for a height of an inch or two into the pipe of a washbowl on the third floor when the pressure is completely off. Bath spray hoses should not be used. Why?

All rooms in which plumbing is installed should be close together. If you study house plans, you will find that many houses are not built according to this rule. The most economical arrangement is to have the kitchen and bathroom adjoining, so that the same set of pipes may serve both rooms, entering them from the dividing wall. Next best is to have the bathroom above the kitchen. Not only does this arrange-



The sewer connections must provide an escape for gas, as well as a means of removing waste water. Study this diagram carefully.



It is possible to connect a water front in the range and a gas-heated coil to the same water tank. Which would provide hot water faster, the water front or the coil?

ment save pipe, but it avoids the need of filling long cold pipes with hot water from the heater.

In the northern states water pipes should be protected from freezing, for expansion of freezing water is sufficient to burst an iron pipe.

All sewer outlets should be sealed with water in a trap under the fixture. Although sewer gas is not a poison, it has an unpleasant odor. If a vent pipe is connected to the sewer and to each fixture, gas pressure does not accumulate to cause bubbling through the traps.

How does the water heater work? The water heater consists of a tank, connecting pipes, coils, and a heater. The tank is usually of iron and often is wrapped in asbestos. The coil may be actually a coil of pipe, or it may be a water back or water front in a stove. A coil is usually enclosed in a cylinder of metal and is heated with a kerosene or gas flame from a burner. The flame passes around the coil of pipe. The water front is a flat box against which the flames move. Cold water flows by convection into the bottom of the coil or water front, and hot water from the top into the tank. A tank may be connected to both a stove and a heating coil, as shown in the diagram.

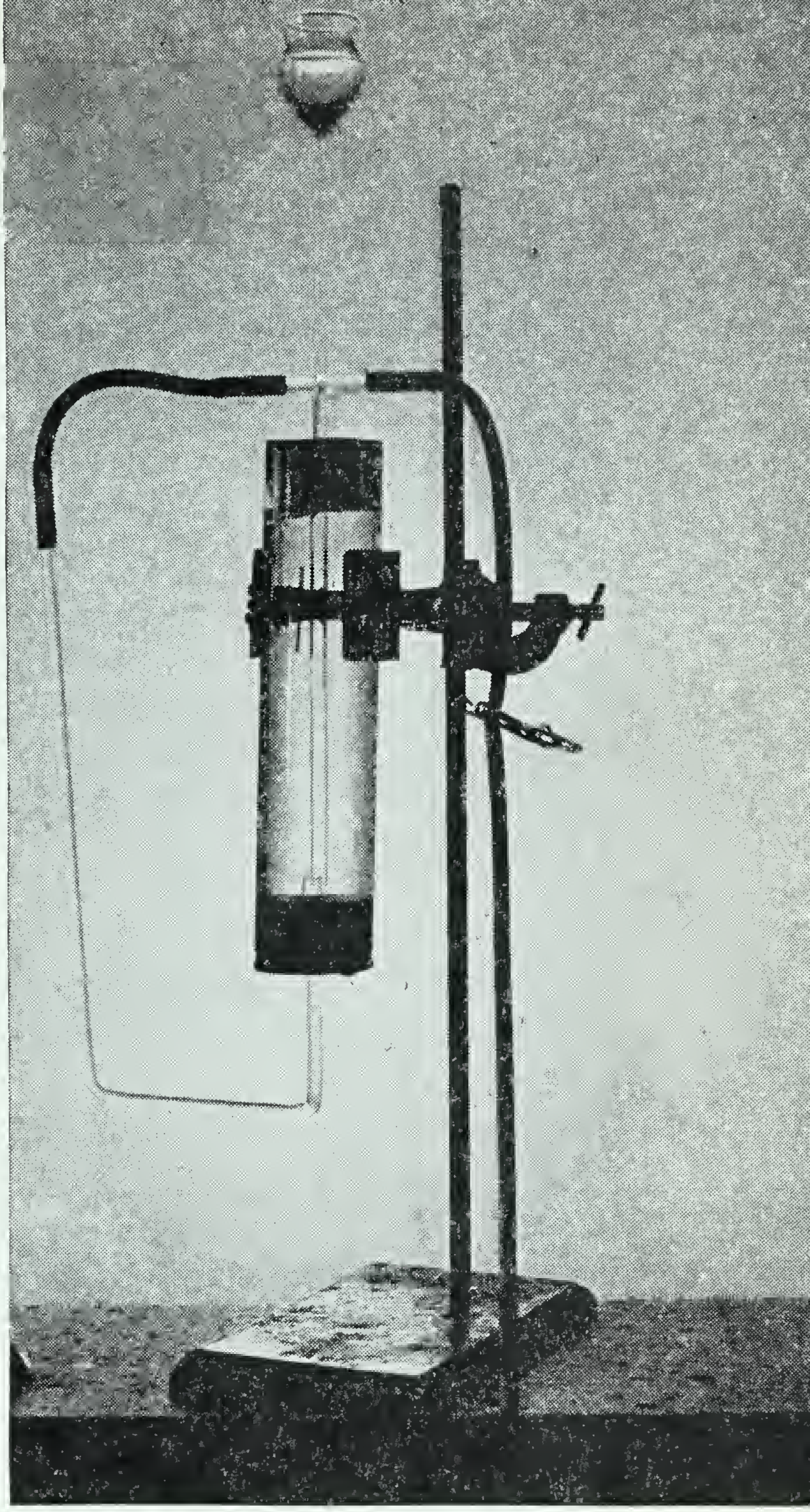
The heating of the tank may be regulated by hand controls, by merely building a fire, by a thermostat and automatic heating control, or by a time clock. Each system has some advantages. Automatic controls usually require electricity.

What fixtures should we select? The type of fixtures one buys is determined by the amount of money available. The

important factor is that they be sanitary. The bathtub should be one that can be easily cleaned, and it should be fitted to meet the floor. The kitchen sink should have a drainboard and should be smooth enough to clean easily. All faucets should be well above the water level of the fixture when it is full of water.

A shower bath is superior in convenience to a tub. It is possible to wash in clean water in a shower. By being careful, a shower can be taken with less water than is required to fill a tub.

How can we keep plumbing clean? The cleaning of porcelain plumbing fixtures is usually done too vigorously. Most scouring powders scratch the surface and cause microscopic grooves which fill with dirt, causing slight but permanent dulling of the color or surface. A better method than using scouring powder is to use a mixture of nine parts whiting and one part tetrasodium pyrophosphate. These materials may be bought through paint and chemical supply stores and will clean new surfaces effectively. For surfaces already scratched, scouring powder is required. Remember that the faster a cleanser cleans, the more it is likely to scratch.



Arrange the demonstration apparatus as shown here.

To keep sewerage pipes open, avoid putting materials into them that do not dissolve or decompose readily in water. Neither cloth nor cardboard should be put into the toilet bowl.

Unless garbage is finely ground by some device such as the "electric pig" it should not be run into the kitchen sink drain. One of the good investments in any home is an incinerator for burning wastes, if regular garbage service is not available.

Soft water reduces clogging of pipes by soap scum and grease. It is well to flush out traps and drains occasionally with several gallons of boiling water.

Every properly installed drain has a cleanout opening which is closed by a screw-in plug. This plug can be removed so that any obstruction may be twisted or pushed from the pipe by use of a long, flexible steel spring. You will find the proper location of cleanouts in the diagram on page 457. Most traps have cleanouts at the bottom. In loosening cleanout plugs, they should not be twisted too forcibly, for broken threads cause leakage.

Demonstration. How Does the Water Heater Work?

What to use: Argand lamp chimney, a one-hole and a two-hole stopper to fit, glass T-tube, thistle tube, glass and rubber tube, ring stand and clamp, burner, pinch cock or clothespin.

What to do: Set up the apparatus as shown in the illustration on page 459. Fill the lamp chimney with water. With the mouth withdraw air from the outlet tube, and when there is no air in the tubes, close the outlet with the pinchcock.

Heat the glass tube with the burner, being careful not to heat it too rapidly. If you wish to show currents more clearly, put a few drops of ink in the thistle tube. When the water seems hot, permit some to run from the delivery tube. Be sure to maintain the level of water in the thistle tube as needed.

What was observed: Describe the action of the heating tank, or draw a diagram of it.

What was learned: Is the heating tank a special use of convection currents? Explain.

Exercise. *Complete the following sentences:* The system of pipes by which —1— is supplied to the house and —2— is carried away is called —3—. Flow of water is controlled by valves and —4—. —5— is kept out of the house by traps. There must be no connection between the city water and the —6—. Water is heated when it flows through —7— passing through a flame. The water circulates because hot water is —8— in weight than an equal volume of cold water. This movement of water is called —9—. If

water pipes are light in color or polished they do not gain or lose heat by —10— so rapidly.

Science activity. Make a model hot-water tank, using cans and copper tubing. It will be necessary to solder the joints where the tubing enters the can.

A Review of the Unit

To build our houses for greatest comfort, we must be able to apply the sciences of physics and chemistry in selection of materials; the laws of heating in selecting a furnace and in constructing and insulating the house; the laws of lighting in placing windows, selecting lighting equipment, and painting the house; the use of measurement in planning the house; and the laws of sanitation in making it safe.

Most of the older houses show little application of scientific laws in their construction. To improve our houses, we need better planning, better use of materials, and more general education of the public and the builders regarding the inefficiency of the older type of house.

An exercise in thinking

I.

Match the principles and related ideas, according to the directions given in the review at the end of Unit I.

List of principles

A. Conduction is the transfer of energy from one molecule or object to another.

B. Convection is the transfer of heat by currents in liquids or gases.

C. Radiant energy travels in waves which move in straight lines through space.

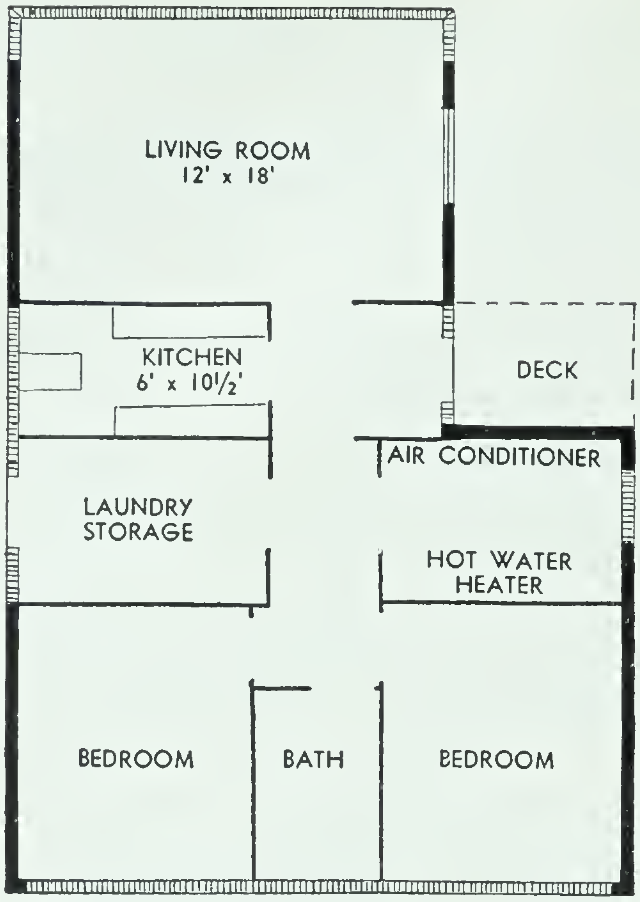
D. Heat and light are reflected by light-colored objects and absorbed by dark-colored objects.

E. Every step in house construction must contribute toward safeguarding health.

F. Humidity refers to the amount of water vapor held in the air.

List of related ideas

1. Hot water accumulates in the top of the heating tank.
2. Rugs cause more accidents than any other single object in



Refer to the test for information.

the house and should not be used.

3. Screens keep out flies and mosquitoes which carry many diseases.

4. Ceilings should be painted white, and walls should be a light color.

5. Metals without insulation are poor housing material.

6. Rate of heating a room is in proportion to the temperature of the radiator.

7. The hot-air heating system causes circulation of air.

8. Moisture is likely to condense in cold walls when air is too moist.

9. Stairs, next to rugs, cause most accidents and are undesirable.

10. A light-colored ceiling is of little use if windows are too low.

11. When a person sits by a fireplace, his face gets too hot, while the room remains cold.

12. Plant fibers are useful in keeping the house warm.

13. A polished, light-colored floor is undesirable.

14. Water flows without being pumped from the boiler to the radiators.

15. Gravity ventilation works only when the room and the outdoors are different in temperature.

16. Relative humidity should be 30 per cent in winter and 60 per cent in summer.

17. The house must be planned to require as little work as possible.

18. A glass window loses heat more rapidly than does the wall.

19. The best color for a roof is white.

20. A radiator should be black and rough finished.

II.

Refer to the house plan above in order to understand better the statements in the lettered group below. Each lettered statement describes a feature of the experimental house, while each numbered statement ex-

plains the reason for using this particular feature. Match the items by writing the letter or letters required after each number.

A. There is only one window in the house.
B. The walls shown by cross lines are made of glass block from a height of four feet from the floor to the ceiling.
C. There is no basement or attic.
D. The laundry and kitchen are side by side.
E. The living space is separated from the sleeping space.
F. The walls shown by solid black lines are made of concrete block, stuccoed outside and insulated inside.
G. The house is placed upon a slab of reinforced concrete.
H. The heating system is a forced, hot-air system.
I. The kitchen is small, and all equipment is closely spaced.
J. There is no dining room, but there is space for eating in the kitchen and in the living room.
K. Storage space is provided for only a small amount of equipment.
L. The floors are of linoleum blocks and require no rugs.
M. There are few broken wall spaces in the house.
N. No fireplace is included in the plan.
O. There are no closets in the house.

1. A good wall is durable, fireproof, and proof against heat losses.
2. A kitchen is a workroom, and the equipment in it should be arranged so as to require little walking when work is being done.
3. A satisfactory floor is insulated so that rugs are not needed.
4. Windows are the worst cause of heat loss.
5. The fireplace is inefficient and upsets forced ventilation.
6. A house must be placed upon a solid foundation to prevent settling.
7. Light should be diffused and the source should be above eye level.
8. The dining room is used for only an hour a day.
9. Stairs occupy space, add to work, and are dangerous.
10. Necessary equipment should be carefully stored, and unnecessary articles should be discarded to prevent fire hazards.
11. The window area of the living room equals 56 per cent of the floor area.
12. Plumbing should be grouped as much as possible.
13. Closets can be replaced satisfactorily by lockers.

14. The bedrooms and bathrooms should be given complete privacy.

15. An unbroken wall space permits one to arrange furniture as desired.

16. The hot-air system of heating is most economical for small houses.

17. A flat roof may be insulated so that no attic is needed.

18. A fan forcing air through screens provides cleaner, more certain ventilation than does natural window ventilation.

19. Glass block is a much better insulator than is window glass.

20. A floor should be of material that can be kept clean with little care.

Some things to explain

1. Make a complete study of your own house, paying special attention to the heating plant, the plumbing, the lighting, the insulating devices, the ease of cleaning, the amount of waste space, the ease of doing work, the number of cracks in floors and walls, presence of insects, suitability of the house to your needs, and its general appearance. Is it a good house?

2. Make a study of prefabricated houses and their advantages and disadvantages.

3. Compare the development of the automobile with the lack of development in housing, and try to explain the difference. Consider the problem from the standpoints of engineering, mass production, competition, sales methods, and general efficiency of the products.

4. Study insulating materials, and make a report on the types which are most suitable for your locality.

5. Why does water vapor condense in walls? When? What harm is done?

6. Why is it dangerous to saturate wallboard and insulation with arsenic compounds? Why is it done?

7. Why are plumbers required to obtain a license before they can carry on their business?

8. It is estimated that maintaining a temperature of 2 or 3 degrees higher than 72 increases cost of fuel 10 per cent. How much could the average family save if women and girls wore long wool and cotton stockings and jackets with sleeves when indoors?

Some good books to read

Bassett, Sara W., *The Story of Lumber*

The Book of Low Cost Houses, Architectural Forum Editors

Earle, Alice M., *Home Life in Colonial Days*
Housing America, Editors of *Fortune*
How to Judge a House, U. S. Department of Commerce
Lescabaura, A. C., *The Home-Owner's Handbook*
Newell, A. C., *Coloring, Finishing and Painting of Wood*
Newell, A. C., *Wood and Lumber*
Pack, C. L. and Gill, Tom, *Forests and Mankind*
Phelan, O. B., *The Care and Repair of the House*
Reisbeck, E. W., *Air Conditioning*
Reisbeck, E. W., *Practical Installations*
Waterhouse, P. L., *The Story of Architecture Through the Ages*
Wilhelm, D. G., *The Book of Metals*

Some interesting motion pictures

Housing Problems. Museum of Modern Art Film Library (*16 sound*)
Forest Treasures. Veneer Association (*16 sound*)
House of Dreams. American Brass Company Y.M.C.A. Motion Picture Bureau (*16 silent*)
Shelter. Erpi (*16 sound*)
Home Builders at Work. Purinton Pictures (*16 silent*)
Colonial Architecture. Y.M.C.A. Motion Picture Bureau (*16 silent or 16 sound*)
Will and Way. (2 reels). U. S. Department of Agriculture (*16 silent*)
Backbone of Progress. American Institute of Steel Construction (*16 silent or 16 sound*)
Science Saves the Surface. Y.M.C.A. Motion Picture Bureau (*16 sound*)
Hot-Air Heating. Eastman (*16 silent*)
Heat and Its Control. Johns-Manville Company (*16 sound*)
Distributing Heat Energy. Erpi (*16 sound*)
Sewage Disposal. Eastman (*16 silent*)

Courtesy George School

UNIT NINE

HOW CAN WE CONSERVE OUR HEALTH?

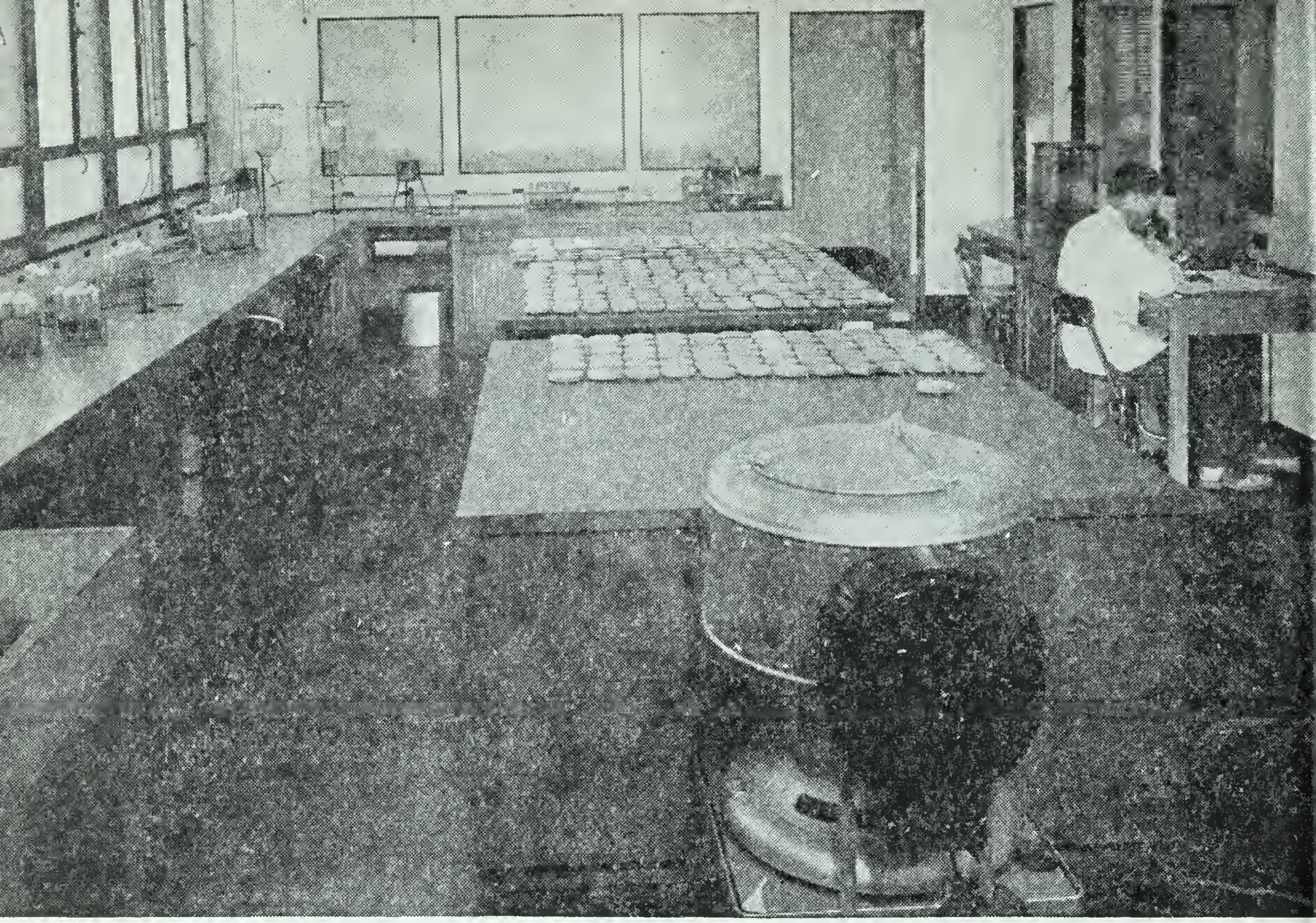
THERE are many things of value which we wish to keep safe for future use. And the most precious among these is health. Keeping healthy is not a simple matter, for our health depends upon many things. It depends upon discoveries made by scientists regarding the causes of and methods for fighting diseases. It depends upon sanitation in our homes and in our cities. It depends upon keeping our bodies in good condition. It depends upon good food, sleep, and exercise. It depends upon freedom from worry, fear, and too much excitement.

Despite the many factors which affect health, the average person is fairly healthy. The conditions under which we live make it easy enough for us to avoid many of the dangers which caused illness in the past. Our water and food supplies are usually safe. Our homes are the cleanest in the world. Our neighbors usually have habits of cleanliness and keep themselves healthy so that they do not carry disease germs to us.

And yet almost everyone should be even more healthy than he is. In any group of school children flat feet, colds, decayed teeth, diseased tonsils, malnutrition, and other defects are common. The average 14-year-old pupil is ill enough to spend five days in bed at sometime during each year. Many thousands of high school boys and girls are in hospitals suffering from tuberculosis. Many people die from smallpox and other preventable diseases.

In many communities there are no systems of water purification and sewage disposal. Many people never obtain medical aid, no matter how ill they may be, but depend upon luck or superstitious practices to save them. There are many more people who do not use toothbrushes than there are who do. There is no bathtub in half the houses of this nation. It is clear that there is still much need for improved ideas and conditions to bring about improved health.

The battle to conserve our health is never won. As long as people exist, there will be bacteria that are adapted to live in their bodies for a long enough time to cause sickness and death. We have before us a problem that is a constant challenge.



Courtesy Minnesota State Board of Health

In a modern laboratory disease bacteria are studied under carefully controlled conditions. Petri dishes and culture tubes are in use. The machine in the foreground is a centrifugal separator.

1. How has scientific medicine been developed?

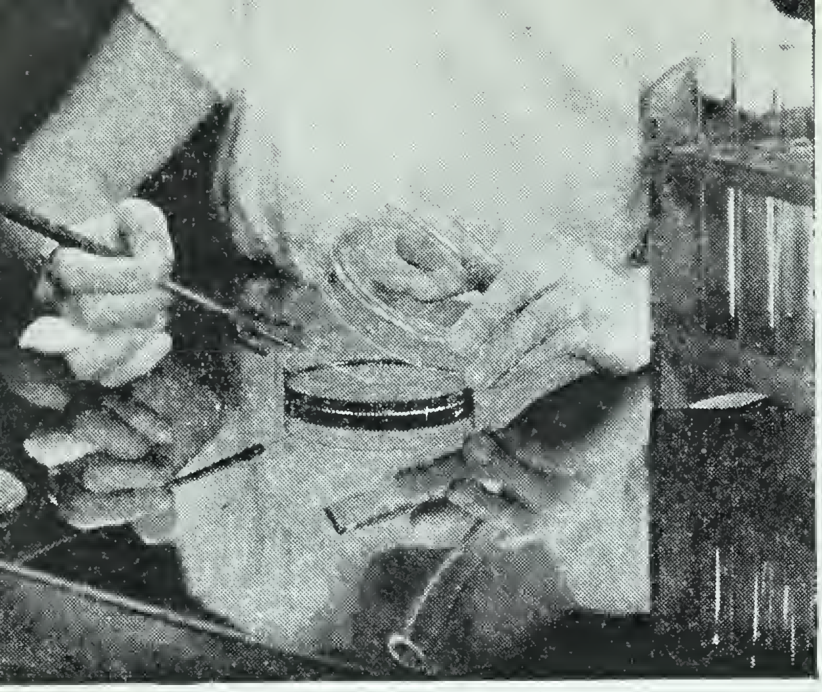
We have come as a matter of course to depend upon medical knowledge to protect us from disease. Such protection has not long been available, nor is it yet available to people of all nations. For modern medicine is a recent science. It has developed from the study of methods of isolating bacteria, from the discovery of use of antiseptics and anesthetics [ăn′ĕs·thĕt′ĭk, a drug which causes loss of feeling] in surgery, from the use of chemistry in purifying and manufacturing drugs, and from many other scientific discoveries. Scientific medicine is actually less than a century old.

What knowledge formed the basis of modern medicine? Ancient medicine developed slowly because of the lack of useful methods of research. The familiar tricks of medicine men, such as making brews of roots, muttering prayers, using charms, and other equally useless activities, slowly gave way to a small amount of medical knowledge developed by trial

and error methods. Hippocrates [hĭ·pŏk′rȧ·tēz], a Greek physician who lived about 2400 years ago, described methods of giving medical examinations, described many diseases, and gave directions for their treatment. The treatment was not often successful. Some 500 years after the work of Hippocrates another Greek, Galen [gā′lĕn], added some information to medical knowledge gained by dissecting animals and studying the arrangement of the organs in the bodies of these animals. From such study he tried to figure out the probable arrangement of the human organs. He also wrote a medical encyclopedia.

This work of Galen—including all the errors—was used as a basis for medical thinking for more than 1400 years. A few discoveries were made by Arabian physicians during this time. But it was not until the work of Vesalius [vė·sā′lĭ·o͝os] that the correctness of Galen's information was seriously questioned. Vesalius studied human bodies and became familiar with the human skeleton. To the knowledge of the ancients, there was gradually added the knowledge of surgery and of many simple medical treatments. It was learned from the work of Semmelweiss [zĕm′ĕl·vīs] that if a surgeon washed his hands in chlorine water, he did not spread infection from one patient to another, but it was not known why. Most surgeons ignored such "unscientific" advice, and their patients generally died. It was in the 1620's that Harvey published proofs of his discovery that the blood circulates through the body.

How did the study of bacteria develop? The discovery of the importance of bacteria in causing disease was a slow process. A microscope powerful enough to show bacteria was made by Van Leeuwenhoek [vän lā′vĕn·ho͝ok′] in 1683. Being able to observe bacteria through a microscope did not prove their relation to disease, of course, but it made the study of bacteria possible. You are familiar with the work of Louis Pasteur in proving that bacteria caused anthrax and rabies. Knowing the cause of these diseases, Pasteur developed the first vaccines that were worked out as the result of purely scientific approaches to the problem. Pasteur's inoculation of a boy to prevent rabies followed by about 90 years Jenner's discovery that the virus [vī′rŭs, a disease-



Courtesy Parke, Davis & Company

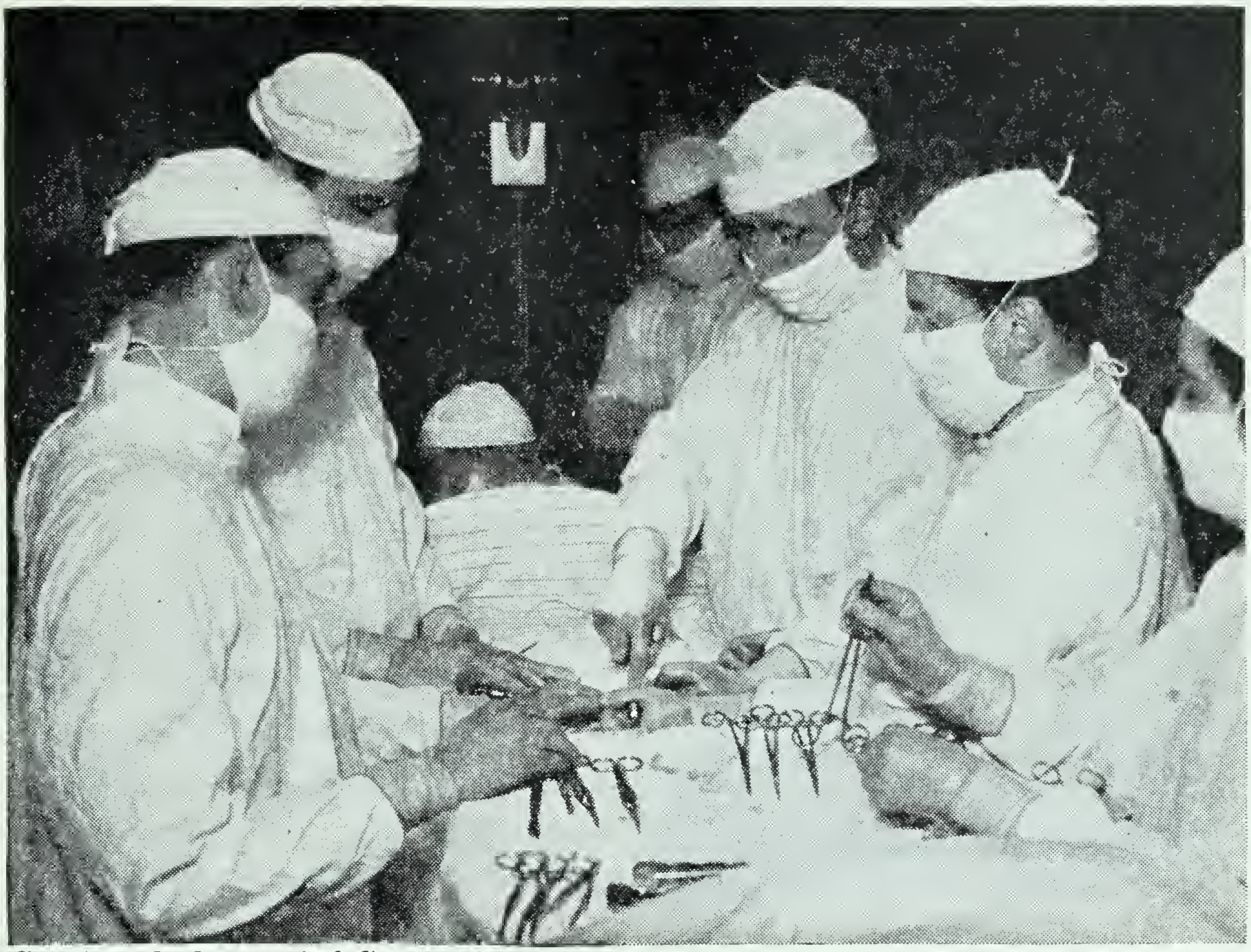
Bacteria of a single type are transferred from one culture to another by dipping them on the point of a needle. The needle is sterilized in the flame of the burner.

producing protein chemical] of cowpox could be used to prevent smallpox. Jenner, however, did not develop scientific proofs of the steps which made vaccination possible, nor did he know what caused the disease.

A great German scientist, Robert Koch [kŏk], developed the first complete proof that a single type of bacteria caused a specific disease. He developed four laws describing steps in the proof: (1) The bacterium must be found in the body of the sick person or animal; (2) a pure culture of the bacterium must be made; (3) another animal inoculated with the bacterium must have the disease; and (4) the bacterium must be found in the body of the second animal.

According to Koch's method, a pure culture of bacteria is made by spreading infected material on a sterile (without germs) gelatin plate. On such a plate, each bacterium develops into a colony of bacteria. A single colony contains only one type of bacteria, although there may be other colonies made up of other kinds of bacteria present on the same gelatin plate. From one of these colonies the suspected bacteria are taken on the tip of a needle and placed on a second culture plate to grow. In this way, various suspected bacteria may be sorted out for study.

Koch used this method to prove that tuberculosis is caused by a bacillus (a rod-shaped bacterium). He took from the lungs of a patient who died from tuberculosis a tubercle (a round growth) and stained the material it contained for examination under a microscope. He found this bacillus was present in all tubercles examined and not present in the lungs of healthy persons. Then the bacillus was grown in a pure culture and injected into a healthy guinea pig. The guinea pig took tuberculosis and eventually died. Koch then



Courtesy Parke, Davis & Company

Here the surgeon is performing an operation inside the abdomen of the patient, who is covered. The assistants and nurses help with the operation, hand the surgeon instruments, and give the anesthetic. What precautions against infection can you see?

examined the tubercles from the lungs of the dead guinea pig and found the same slender bacillus with which he started.

This discovery of the germ of tuberculosis was the beginning of similar studies of many other diseases.

How has surgery been developed to protect our lives? There are some diseases which cannot be cured by ordinary treatments with drugs and careful living, nor can they be prevented by inoculation. Some such diseases may be cured quite successfully by surgery. The most common of the major surgical operations is for treatment of appendicitis. The safety with which this operation is possible today depends upon two important discoveries.

An English surgeon, Lister, read of Pasteur's discoveries of the relation of bacteria and disease. To prevent the entrance of disease germs into wounds created by surgery, Lister used carbolic acid for an antiseptic. He dipped sponges

and instruments into the solution and kept towels soaked with the solution around the wound. He washed the wound with carbolic acid solution, and for a while even sprayed the air of the room with it.

Today the use of such powerful and irritating substances is unnecessary. Instruments are made sterile by boiling, boiled rubber gloves are worn, and sponges are baked to kill germs. In many modern operating rooms the air is sterilized by ultraviolet light. The surgeon wears a mask to prevent spray from his mouth entering the wound. The skin to be operated upon is washed with pure alcohol.

A second important factor in making surgery safe is the use of anesthetics. The discovery of anesthetics is shared by a number of men who carried on the work at the same time. In 1842 ether was first used to produce unconsciousness in patients to prepare them for a surgical operation. Other chemicals, nitrous oxide and chloroform, were also used. Any one of these three gases can be breathed into the lungs and absorbed, and soon causes a deep sleep. Not only does use of an anesthetic reduce the pain from operations, but it actually protects the nervous system from shock resulting from pain. Before the discovery of anesthetics, nervous shock following operations was a frequent cause of death.

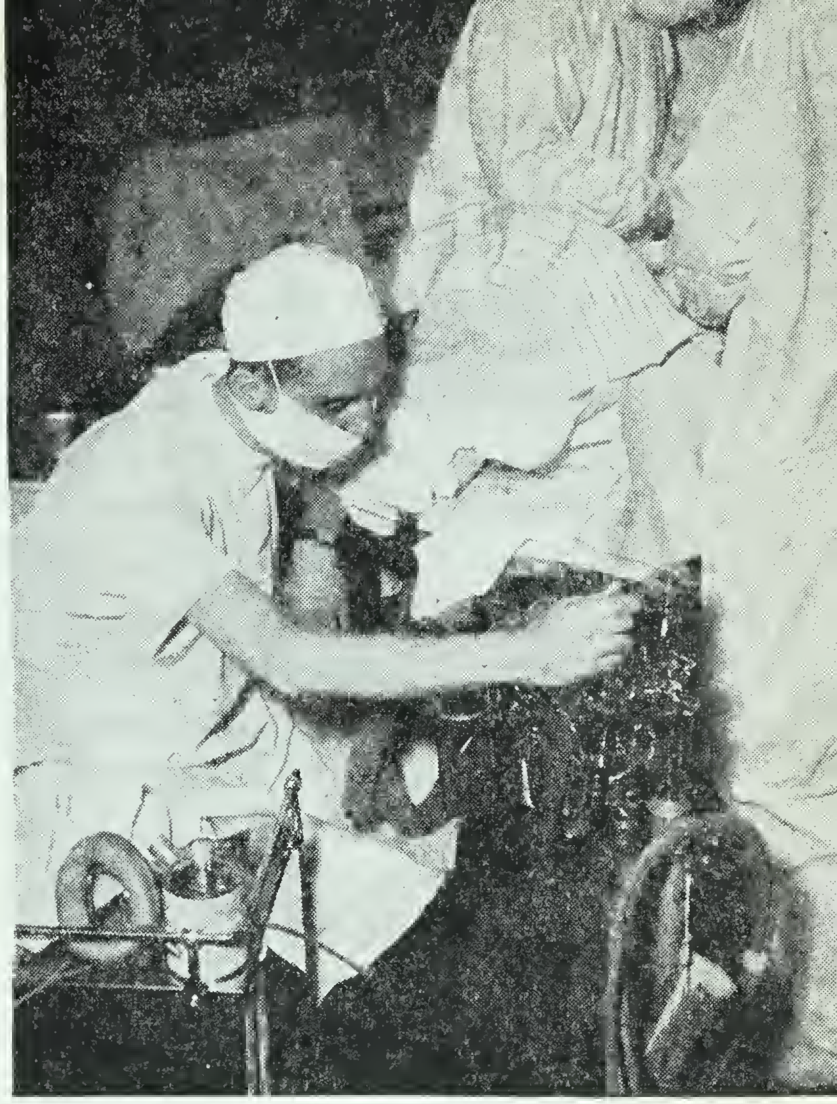
While no operation can be said to be entirely safe, it is true today that if an operation is undertaken while the patient still has a reasonable chance to live and is performed by a competent surgeon, the chances of recovery and improved health are excellent. Many lives are saved daily by operations for tumors, appendicitis, cancer, and other less-known illnesses.

Has scientific medicine improved our health? The conquest of disease, like other results of use of science, has depended upon working out methods of attacking and solving problems. These methods are now quite well worked out for a large number of diseases. Inoculation and vaccination are possible means of preventing absolutely such diseases as smallpox, typhoid, scarlet fever, and diphtheria. Making of serums useful in treatment of diseases is a standard practice.

Surgery prevents many deaths from appendicitis. Better methods of treatment have reduced the death rate from pneumonia to a marked extent.

Babies have better chances to live today than ever before. The baby born in a hospital, kept in a glass-walled room, fed pasteurized or mother's milk, and kept away from adults is very likely to live. Contrasted with the treatment of babies born 100 years ago, modern babies encounter little risk. The old practice was for the baby to be born at home, to be handled by any adult who was around, to be fed impure milk or even solid foods, and to be given water containing bacteria.

The practical test of the value of modern medicine is in the reduced death rate, in the reduced amount of sickness, and in the increased average age of the population. See if you can obtain figures to prove this statement.



Courtesy Parke, Davis & Company

When "gas" is given as an anesthetic, not much is visible. The patient is covered with cloth, while the attendant regulates the flow of the anesthetic through the valves and tubes.

Filmstrip: Robert Koch (tubercle bacillus). Metropolitan Life Insurance Co.

Exercise. *Complete the following sentences:* A chemical which retards growth of bacteria is an —1—. A chemical which causes loss of feeling is an —2—. Semmelweiss used —3— water as an —4—. —5— proved that blood circulates. Putting a chemical into the body to prevent disease is called —6—. The bacterium proved by —7— to cause tuberculosis is a —8— type. Lister used —9— for an antiseptic. Ether is a commonly used —10—.

Science activity. Report in class on the work of the men named in this problem. Emphasize their scientific contributions and not their personal lives.

2. What diseases are most dangerous?

Because of man's conquest of disease, many of the fatal diseases of the past are no longer a source of danger to the

average person. Although the plague, leprosy, typhus, smallpox, typhoid, and many other diseases are as deadly as ever, we know how to prevent their spread, and we need not fear them if we continue to keep them under control.

There are two types of dangerous illnesses today. The first type is that which is fatal. The second is the type which causes serious aftereffects or which causes much loss of time.

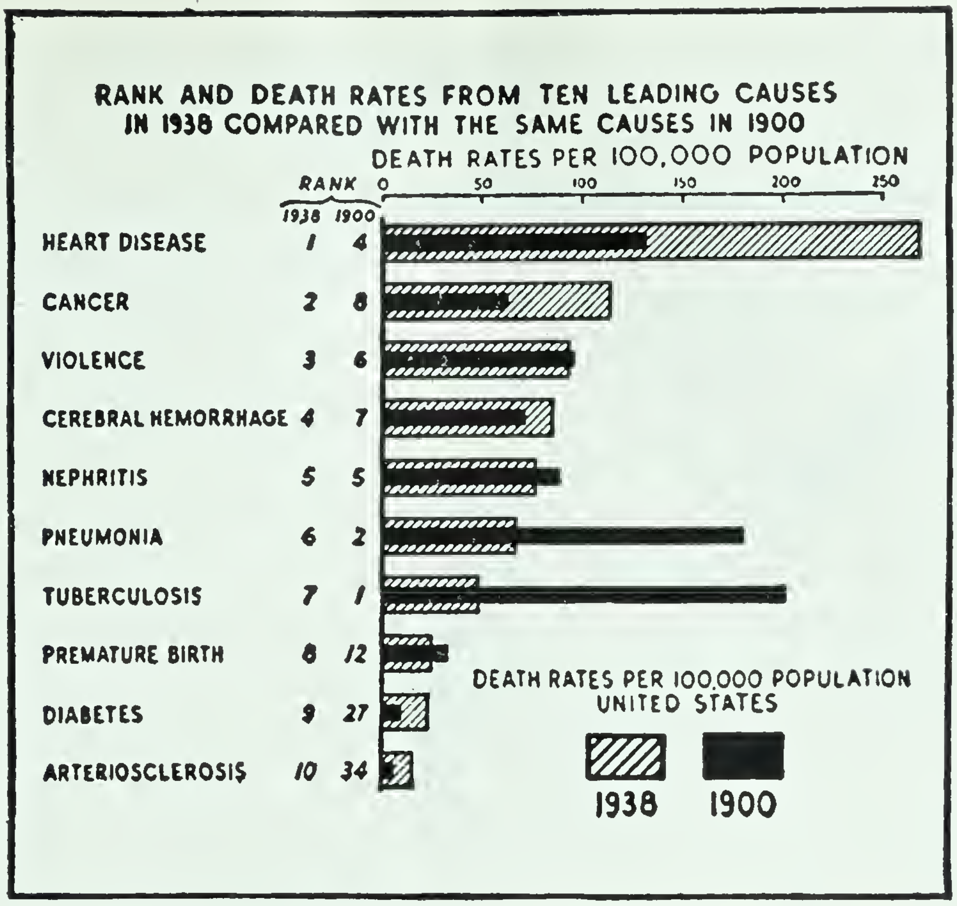
What are the leading causes of death? At present more people die of heart disease than from any other cause. There are many causes of heart disease. Among them are infections resulting from many other diseases which are not directly fatal. One such disease is rheumatic fever, which particularly affects children. Another such disease, syphilis, is generally transmitted through the reproductive organs. Some heart disease may be caused by alcohol, some by misdirected nervous energy. Most deaths from heart disease come to those who are in later middle age or in old age, although the beginning of the illness may have been the result of an earlier infection.

Cancer is second of the most deadly diseases. It occurs when certain cells of the body grow at an unusual rate and in unusual ways. These wildly-growing cells may destroy normal tissue or may manufacture substances disturbing to the organs of the body. While cancer may be controlled if discovered in time, its cause is not yet known, in spite of the efforts of thousands of scientists and the expenditure of great sums of money. Cancer, too, is chiefly a disease of the elderly.

Violence—automobile accidents, burns, falls, murder, suicide, industrial accidents, sports accidents—ranks third as a cause of death. It is the leading cause of death among school children and is too often the result of their lack of education regarding rules of safety.

The fourth and fifth causes of death result from the breaking down of the blood vessels of the brain and infection and breaking down of the tissues of kidneys. These diseases also are most likely to attack the older people.

The sixth cause of death in order is pneumonia. There are more than 30 types of pneumonia, and while treatments for many types have been worked out through use of serums and drugs, it still is a deadly disease. It is contagious and



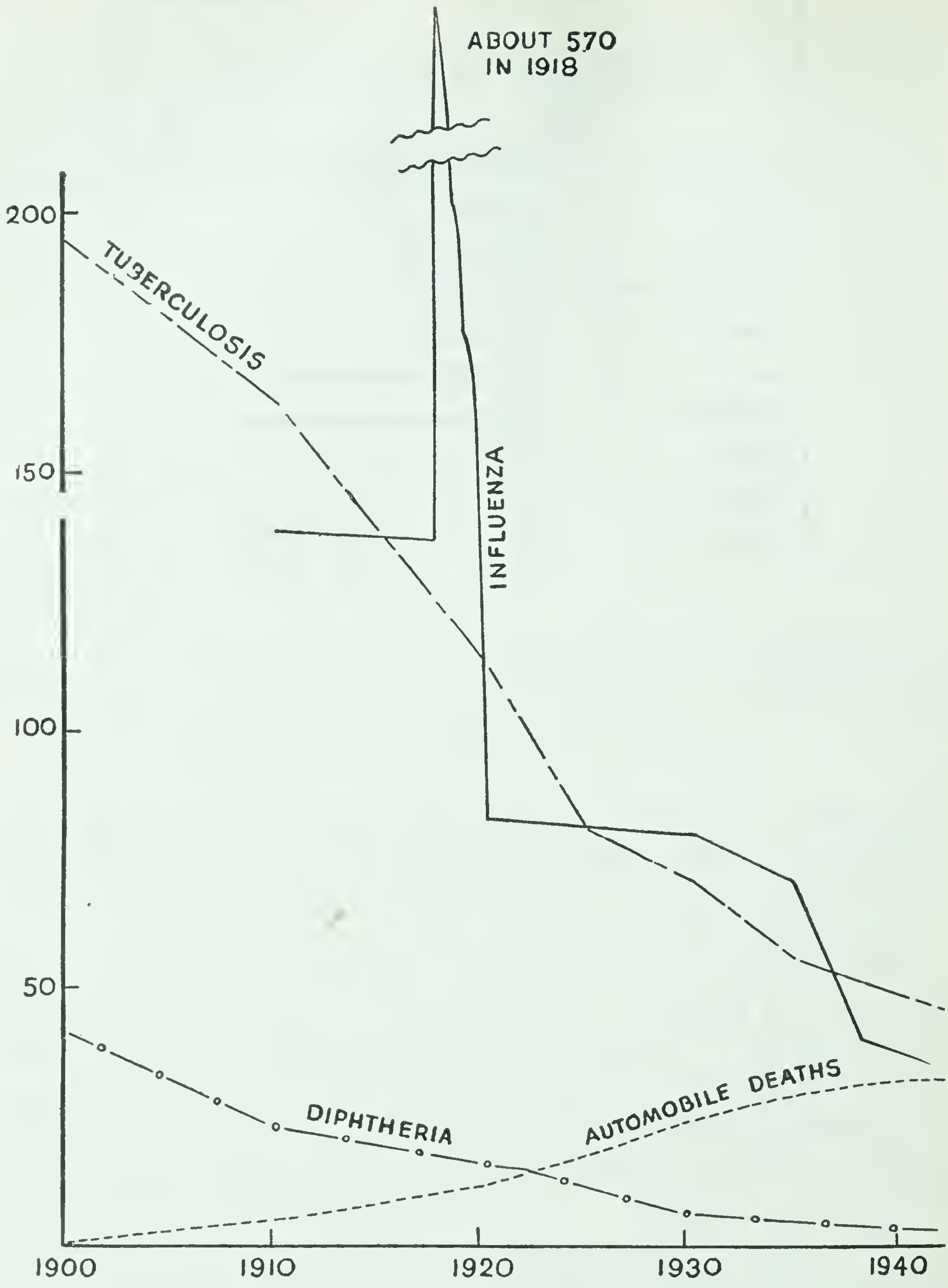
Courtesy Metropolitan Life Insurance Co.

What disease has made the biggest gain as shown on the chart? Against what disease has man made the biggest gain?

may attack people of any age. It most often follows a cold, influenza, or some other weakening disease. To avoid pneumonia one cannot be too careful to remain in bed until he is completely recovered from colds and influenza.

Tuberculosis is one of the few diseases that is more common among people in their teens and twenties than among older persons. It ranks seventh in causing death, and it attacks those who are in poor physical condition. Tuberculosis is contagious and is spread by kissing, by mouth spray, by putting infected articles into the mouth, and in other ways. Girls are more likely to have tuberculosis than are boys.

The eighth largest number of deaths occurs in infancy. Many babies are born without enough vitality to live or lack full development of all their organs. In some cases a lack of food or the illness of the mother may be a cause of the death of the baby. Ninth in the list of deadly diseases is diabetes, which is caused by destruction of small bodies in the pancreas. These bodies normally manufacture a chemical which regulates the use of sugar in the body. If they are



A comparison of four causes of death shows a steady decline in the death rates per 100,000 for tuberculosis and diphtheria. The death rate from automobile accidents has been steadily increasing. The death rate from influenza, an epidemic disease, does not follow a regular trend.

destroyed, sugar accumulates in the blood and is eliminated through the kidneys, while the patient slowly starves or dies from infection resulting from the upset condition. Diabetes can be controlled by use of insulin which is injected into the blood stream. Many people who have diabetes live long and useful lives because of the discovery of insulin by Dr. Banting and because they eat carefully selected foods.

You will note, perhaps, that most of the deadly diseases are those which attack older people. This situation results, of course, from reducing the number of deaths of younger people from infectious diseases. Otherwise there would be few people left to become old. Never before have people lived long enough to die of many of these old-age diseases. The average age at death today is more than 60 years, yet only 100 years ago it was about 30 years. It is said that the average age at death in ancient Rome was 19 years.

What are the disabling diseases? The common cold causes more days lost from normal activity than does any other disease. Colds are contagious. They are caused by a virus. Colds cause few deaths, but they prepare the body for serious aftereffects. There is no effective medical treatment for the common cold. Drinking alkaline solutions or fruit juices, use of aspirin, taking cold pills, use of vaccines, eating onions, use of ultraviolet lamps, changing climates, and wearing poultices are of no use. Use of nose sprays is not only valueless, but often dangerous, for the spray may contain oil which enters the lungs, making a center of irritation in which pneumonia germs may lodge. Cough drops and sirups are merely flavored sugar and are useless. The only effective treatment for a cold is to go to bed and to eat a reduced amount of food until recovery takes place. If a fever occurs, call a doctor. The "cold" accompanied by a fever may be something more serious. Above all, do not have visitors or go into crowds to spread the cold to others.

Measles and scarlet fever produce serious aftereffects. Both may cause permanent injury to the eyes or injury to the ears resulting in loss of hearing. Pneumonia may follow either disease. It is essential that good medical care be given for measles and scarlet fever and that quarantine be observed. Measles is extremely contagious, and

Photo by U. S. Forest Service

A camper who shows consideration for others by digging leaves away from his fire and by leaving the camp clean is practicing a hobby that leads to a mentally healthy state.

no means of protecting the body against this infection has been found. Scarlet fever, of course, may usually be prevented by inoculation.

Infantile paralysis is not a common disease, but it frequently causes serious injury to the muscles of the body. Recovery may be followed by loss of use of the limbs. Treatment consists of tedious massage, exercise, and effort in learning to use the injured part of the body. Many do recover entirely, but the effects are so serious that taking of precautions against infection is essential.

The exact permanent effect of contagious disease on the body is not well known. Injuries, infections, and even minor sprains may apparently be cured and forgotten, only to reappear as causes of other more serious types of illness in old age. Just how many deaths result from heart disease caused by injury suffered in youth is impossible to know. There seems to be no logical reason why people should ever die of old age, for age itself is not a cause of death. Yet no person has ever lived on indefinitely, for so many strains occur in ordinary living that eventually we all die.

What is mental illness? Mental illnesses may result in death, but they more often cause disability. They last for a long time and often result in the complete inability of the afflicted person to live a normal life. There are in hospitals today more patients suffering from mental than from physical illnesses, but this does not mean that more people are mentally ill than are physically ill every year. Rather, it indicates that those who are physically ill soon leave the hospital, and their places are taken by others; while the mentally ill may be required to stay in the hospital for months or even years.

Mental illness is indicated by unusual behavior or by beliefs not founded upon any reasonable evidence. Some men-

tally ill people are alternately very happy—loud and uncontrolled—and then very depressed—so sad that they refuse to do anything that is normally expected of people. Others suffer from beliefs that their lives are being threatened or that they have great wealth or that they are some great and powerful person. Others are unable to make ordinary decisions and unable to conduct themselves according to accepted standards. They may resort to fits of uncontrolled anger or to lying or to senseless stealing. These are but a few of the types of mental illness.

The brain constantly gives off electrical waves as the nerves carry on their work. The brain waves of normal people are regular and produce typical patterns when the nerve currents are caused to make a line graph upon a chart. But from the brains of those suffering from certain types of mental disease come currents which produce wave patterns of unusual designs or irregularity. Such wave patterns indicate that certain mental diseases result from wrong functioning of the nerves of the brain. Other types of mental disease cannot be diagnosed readily, or at all, except by observation.

Many mental diseases are mild and make people "queer" rather than actually ill or unable to get along. There are different degrees of mental sickness just as there are of physical illness. Mental disease is preventable to a large extent, if people live happy, normal, lives and are physically healthy.

Treatment of mental disease is today advanced only far enough to recognize the disease and to cure an occasional patient. It is hoped that this will be one of the next great classes of disease to be overcome by scientific methods.

Exercise. *Complete the following sentences:* The deadly disease most dangerous to teen-age people is —1—. The disease most likely to follow careless treatment of a cold is —2—. School children are in greatest danger of death from —3—. —4— is a disease resulting in loss of sugar from the body and is treated by use of —5—. The best treatment of a cold is to —6—. Loss of hearing may follow —7— or —8—. Scarlet fever may be prevented by —9—. More than half the people in hospitals at any time are —10— ill. Some mental illness may be diagnosed by studying —11— patterns. A —12— is a disease-producing chemical.

From the Selznick International Production "Gone with the Wind"

When hospitals were merely large bedrooms and nurses were willing but untrained volunteers, infection and contagious disease killed more people than medical skill could save.

Science activity. Make a study of causes of absence from your school for the past two or three months.

3. Can we be safe from infectious disease?

Although infectious diseases are no longer the chief causes of death, as they were 50 years ago, we can never safely relax our efforts to protect ourselves from them. Only a few years ago, between 1917 and 1920, the greatest epidemic of all time swept the world, leaving behind between 20 and 30 million dead. This killer, influenza, still has not been conquered. There are many other deadly diseases, constantly ready to break forth if we become careless.

Can we avoid contact with germs? If we could avoid contact with all germs, we could avoid infectious diseases. But there are so many ways that germs are spread and so many kinds of germs that it seems unlikely that we will ever be completely successful in our efforts. At the present time, on any winter day one person in 40 is ill with some contagious disease.

Many diseases are spread because of carelessness or selfishness. A person who knows he is ill and who does not stay home or make any effort to protect others spreads his germs to cause disease. In other cases germs are spread before any definite symptoms of the disease are apparent. There are, unfortunately, a number of diseases which are most contagious just before the symptoms appear or before the disease can be identified.

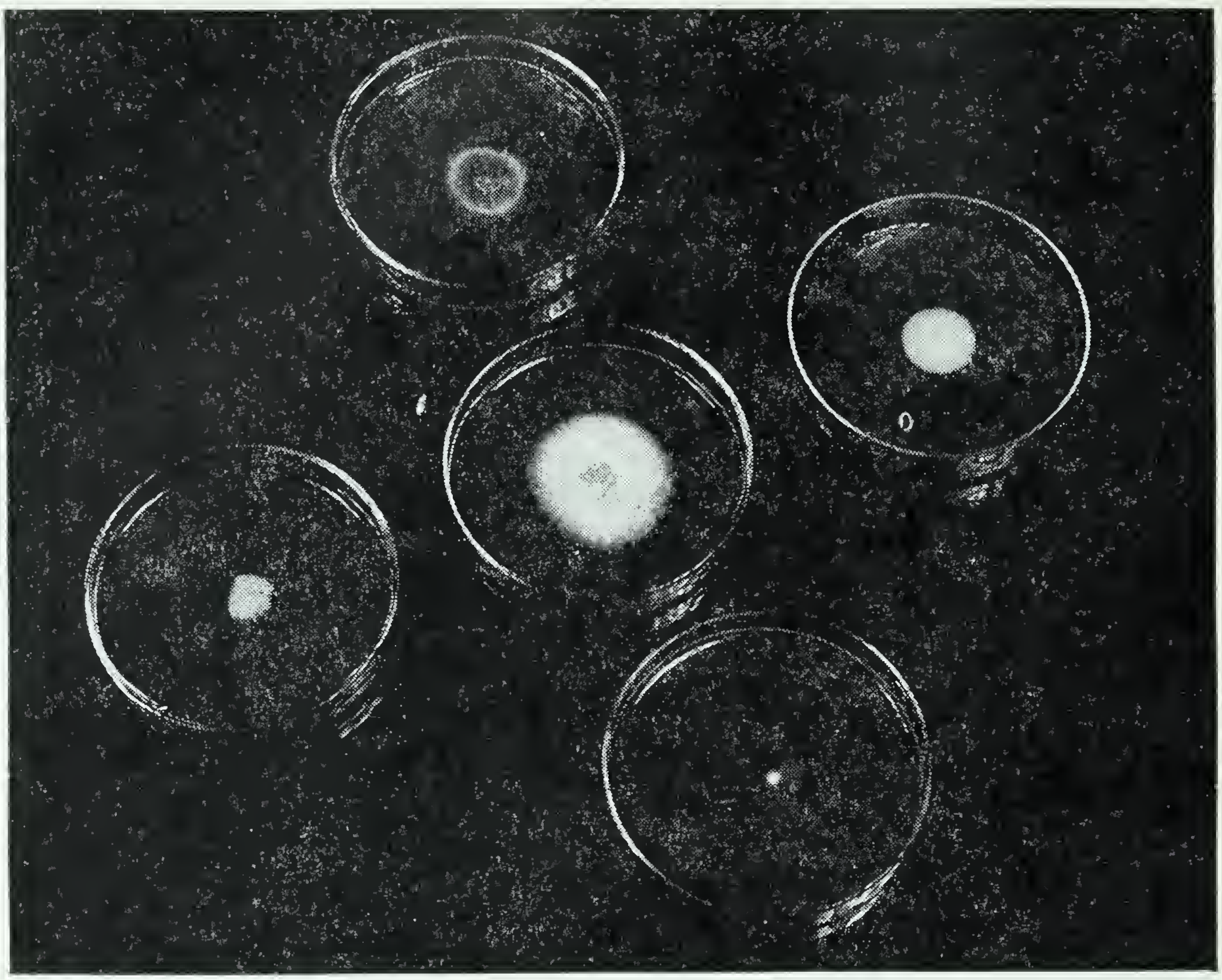
There are many ways of spreading bacteria other than by contact with the ill. Some diseases are spread by mosquitoes; some by flies; some in food; some in water; some by farm

animals, such as cows, pigs, and horses; and some by wild animals. The table shows the causes and methods of spreading certain diseases. The means of preventing the disease depends in part upon the way it is carried.

NAME OF DISEASE	CAUSED BY	CARRIED OR SPREAD BY	MEANS OF PREVENTION OR CONTROL
Bubonic plague	Bacillus	Rat fleas	Killing rats and rodents
Diphtheria	Bacillus	Contact	Isolation; toxin-antitoxin
Influenza	Virus	Contact, animals(?)	None is known
Lockjaw	Bacillus	Soil, manures	Sterilizing wounds
Malaria	Protozoa	Mosquitoes	Killing and controlling mosquitoes; screening houses
Measles	Virus	Contact	Isolation
Pneumonia	Coccus	Contact	General body health; preventing contact
Rabies	Virus	Dogs, foxes	Controlling dogs, etc.; inoculation
Scarlet fever	Coccus	Contact	Isolation; inoculation
Smallpox	Virus	Contact	Vaccination; quarantine
Tuberculosis	Bacillus	Contact, food, flies	Avoiding contact; good general health
Typhoid fever	Bacillus	Water, food, flies, contact	Water purification; food inspection; inoculation
Yellow fever	Virus	Mosquitoes, wild monkeys	Controlling mosquitoes; screening houses

Can germs be prevented from doing us harm? You know, of course, that we can avoid smallpox by vaccination, typhoid fever by inoculation, and diphtheria by the toxin-antitoxin treatment. These measures are effective only if people use them. In states where vaccination is required by law there are practically no deaths from smallpox, but in states where the individual is responsible for being vaccinated, the death rate is much higher. It is desirable to require every school child to be made immune to these contagious diseases for which there is a means of absolute prevention. If your state does not have laws requiring this, they perhaps have not been passed because of public indifference.

Is there hope of preventing diseases now incurable? There is no definite cure known for many diseases. Yet



Courtesy Parke, Davis & Company

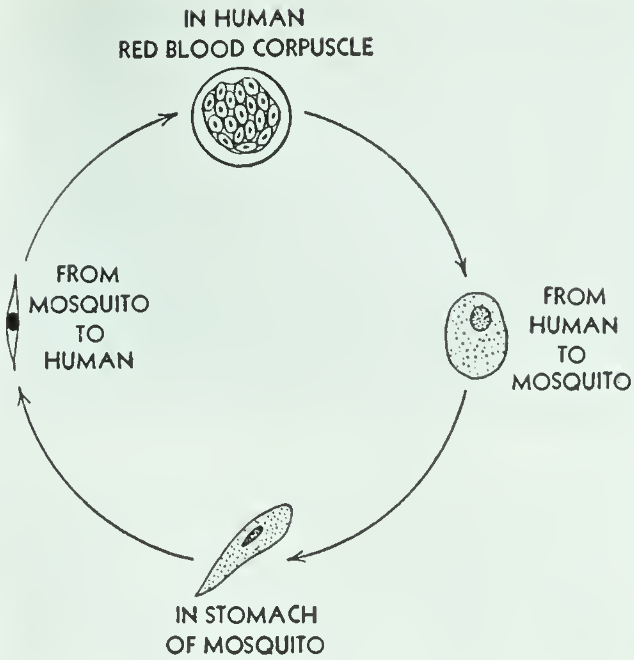
It is not enough to know that germs cause disease. It is essential to know what germs cause what disease. Here are five types of fungi which cause five different types of skin disease.

these diseases, like the ones for which we now have successful treatments, will probably yield in time to some kind of treatment. For example, there have been many attempts made to find a serum to prevent or cure influenza, and tests indicate that the search may eventually be successful. The conquest of some diseases may await entirely new methods of control, for there is no reason to believe that every possible method of fighting germs has been discovered.

Successful control of germs depends in part upon knowing the characteristics of the germ. For the viruses this has been almost impossible, because they are so small. Until recently it was not known whether they were organisms or chemicals, but the best evidence indicates that they are very complex chemicals. It may be possible that the electron microscope can be used to photograph them. This micro-

scope, which is 30 times more powerful than the ordinary microscope, focuses a beam of electrons by means of magnets to cast an image upon a photographic film. The success possible with this microscope is not known at present. It has been found that the influenza virus is barely visible when magnified 25,000 times.

Chemists are studying methods of finding chemicals which will destroy germs, either in our bodies or before they reach us.

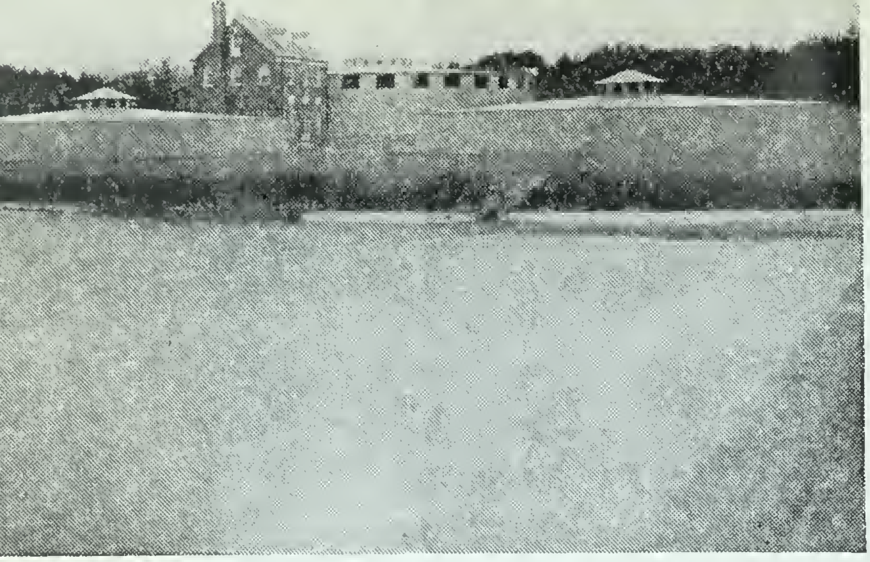


The protozoa which causes malaria goes through several forms as it is passed from mosquito to human and back to mosquito.

Can the community protect us against disease? The least that any community, however small, can do to protect its citizens is to provide pure water and to regulate the sale of milk. Inspecting stores and restaurants, providing opportunities for recreation, controlling the ill, arranging for hospital treatment for the poor, and eliminating menaces to the health of its citizens are among the many added responsibilities of larger communities.

To provide pure water, it may be necessary only to find a pure supply and to deliver it through pipes in a sanitary manner. However, most communities must purify their water by killing disease bacteria in it. This is accomplished by adding chlorine to the water and storing it for 24 hours in order to give the chlorine time to act. If the water is muddy, the most economical way of clearing it is to run it through a settling tank. To speed the settling, a floc is made by adding lime and alum to the water. These chemicals combine to form a fibrous, jelly-like compound which settles and takes with it fine suspended particles. If the water is run through a filter, the floc increases the effectiveness of filtration.

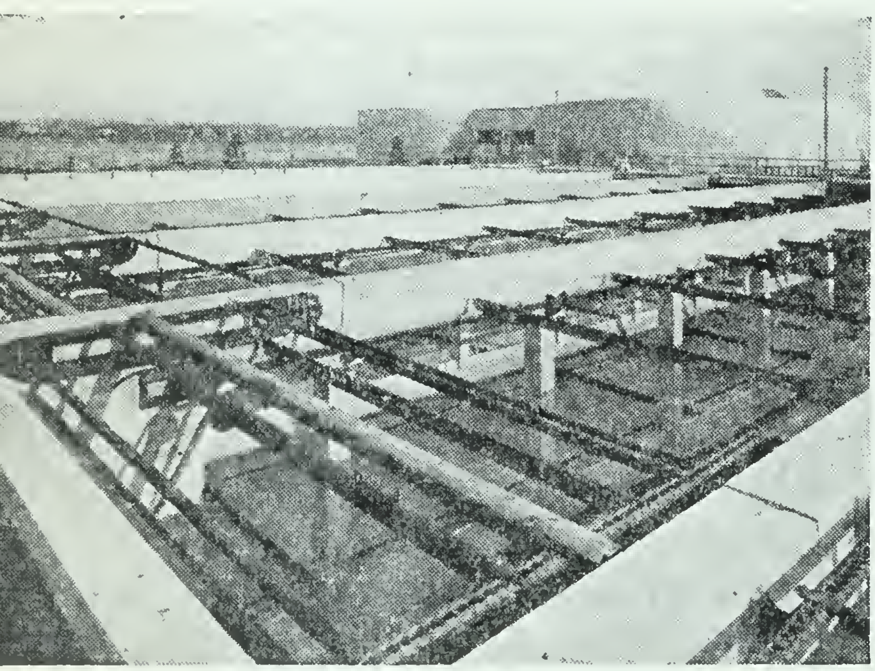
It is almost impossible to produce milk pure enough to be safe for use without pasteurization, and it is probably not good economy to try to do so. It is a simple matter to heat



Courtesy Chicago Bridge and Iron Company

Treatment of water and sewage is so important to public health that no town, however small, can afford not to have a publicly owned and operated water and sewage system. The sewage settling tanks below are equipped with machinery to scrape sludge along the bottom into outlet pipes. Proper disposal of sewage is an important community problem.

Courtesy Department of Public Works, New York City



milk to 145 degrees Fahrenheit and then to cool it to 50 degrees. Not only is such milk safe, but it keeps better, which is an important factor in selling milk at a profit.

The community has the responsibility of seeing that sewage does not contaminate the water supply. Another important responsibility is to provide medical care for the poor, for it is often in the poor sections of cities that epidemics start. All citizens are in danger when any are ill.

Demonstration. How Is Water Purified?

What to use: Test tubes, one-hole stopper and delivery tube, manganese dioxide, hydrochloric acid, alum, calcium oxide or limewater, soil, filter paper, funnel, rack, pond water.

What to do: Mix soil and water to make a muddy suspension. Set one test tube of the suspension aside to let it settle. Filter another test tube of water through the filter paper.

Dissolve a lump of alum in one-eighth of a test tube of hot water, and add it to three-fourths of a test tube of the suspension. Add one-eighth of a test tube of limewater to the mixture, and shake it. Set it beside the other tubes.

Prepare chlorine by pouring 5 cc of hydrochloric acid over a gram of manganese dioxide. Warm it gently. Bubble the gas into tap water. Smell and taste the tap water. If pond water or

water from the aquarium is available, examine it for small organisms. Then bubble chlorine into the water, and after a few minutes examine it again.

What was observed: Compare the appearance, probable cleanliness, and freedom from bacteria of each of the samples.

What was learned: How is water purified?

Filmstrip: How the mosquito spreads disease. Bray-Eyegate.

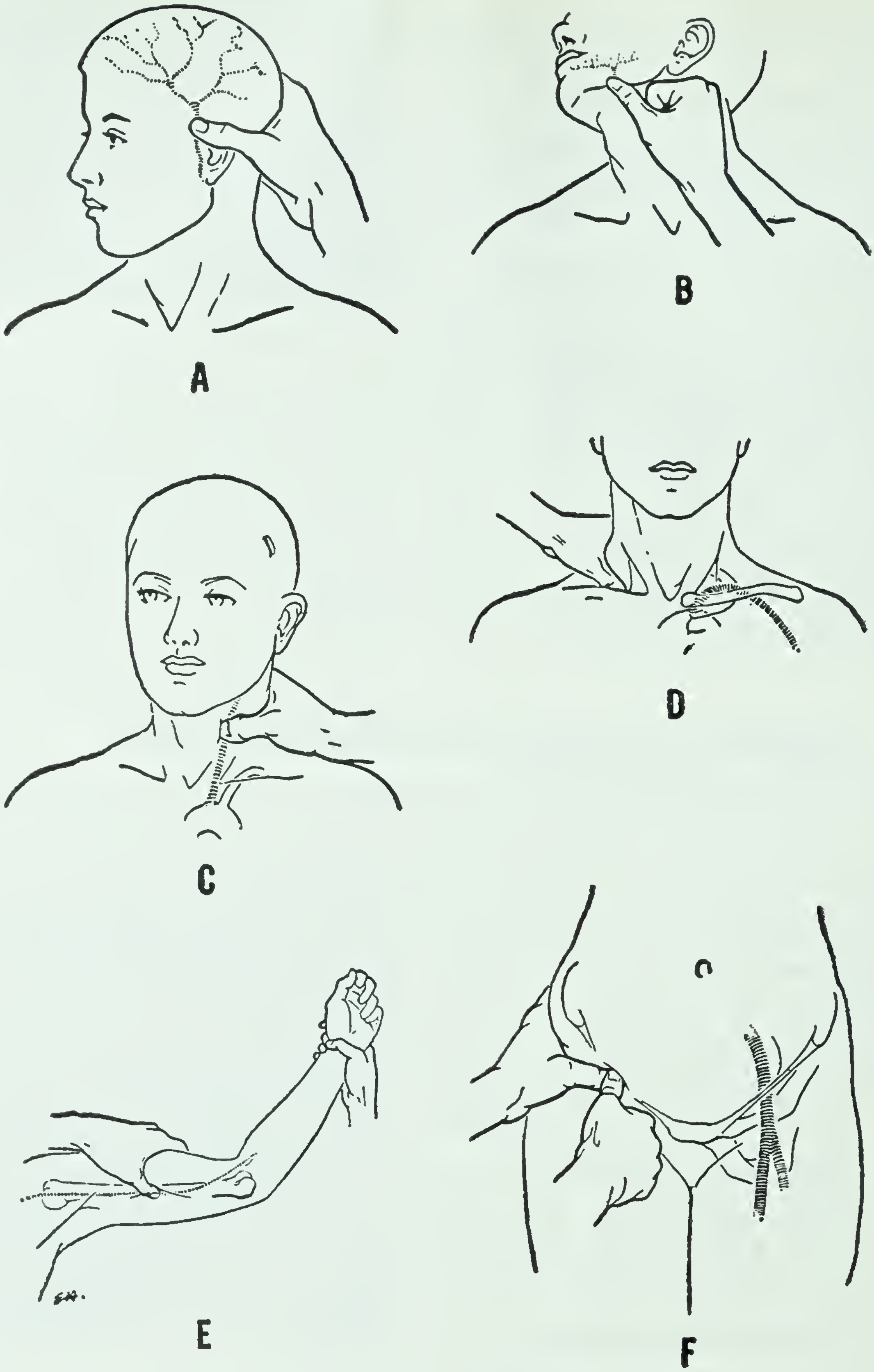
Exercise. *Complete the following sentences:* The two most common causes of contagious disease are —1—, which are small living organisms, and —2—, which are too small to see through a microscope. We are —3— to a disease which we cannot catch. Everyone should be —4— to prevent smallpox. Mosquitoes transmit —5— and —6—. The —7— microscope magnifies objects thousands of times. Sediment may be removed from water by —8—. Bacteria in water are killed by —9—. Alum and lime combine to form a —10—.

4. How can we apply first aid to save lives?

While it is unwise for anybody but a doctor to treat ordinary illness, it is essential that everyone should know what to do to save life in case of serious accident. The most common accidents are automobile accidents, falls, burns, drowning, poisoning, snake bite, and electric shock. In treating the victim of an accident, it is just as important to know what not to do as it is to know what to do.

What should we do in case of an automobile accident? The automobile accident often causes broken bones, serious cuts, and severe internal injuries. One thing not to do is to move the patient to an upright position. If the victim is moved, a broken rib may puncture the heart or lungs, a broken vertebra may sever the spinal cord, or a splintered bone may cut an artery.

If there is severe bleeding, immediate treatment is necessary. The major arteries of the body come near enough to the surface at certain areas, called pressure points, that pressure properly applied will stop circulation. To stop bleeding in areas supplied by these arteries, pressure is applied upon these points by pressing them firmly with the fingers. If the bleeding is from an arm or leg, pressure may be applied by



From *First Aid in Emergencies* by Eldridge L. Eliason (Lippincott)

Bleeding may be stopped by applying pressure directly to the arteries supplying blood to the bleeding area. Pressure applied as shown at **A** stops bleeding from the scalp; as at **B**, from the face; as at **C**, from the neck; as at **D**, from the high shoulder and arm; as at **E**, from the lower arm; and as at **F**, from the leg. You should memorize these pressure points in order to know how to stop bleeding with the hands or with a tourniquet.

means of a tourniquet [to͝or′-nĭ·kĕt]. A tourniquet is a broad band of cloth which is tied loosely around the limb. Above the pressure point a solid object, such as a stone or potato, is put into the tourniquet, and on the opposite side of the limb a stick is slipped beneath the band and twisted until bleeding stops. (*A tourniquet must be loosened every 10 minutes to avoid blood poisoning!!*)

From *First Aid in Emergencies* by Eldridge L. Eliason (Lippincott)

Some torn cloth and two boards have been used to make splints for a broken forearm. The arm should be placed in a sling after being put in the splints.

In extreme cases lives have been saved by grasping the cut ends of blood vessels and holding them shut with the fingers.

If the patient is not bleeding noticeably, the limbs may be gently straightened and the victim laid gently on his back. But if you have any reason to suspect that an arm or leg or the back is broken, don't under any circumstances try to straighten that part of the body. (*Don't try to lift the patient.*) Station someone on the highway to slow traffic to prevent further accidents, and call the highway or city police and the ambulance.

If it is absolutely necessary to move a patient who has a broken bone, the bone must first be held firm with splints. A splint is a series of rods, sticks, or boards bound around the limb with strips of cloth. Never use cords. The splints are tied in place so firmly that the limb cannot possibly bend. Yet the binding must not shut off circulation. Splints should be padded for comfort.

When the splints are applied and bleeding is stopped, a stretcher may then be slipped beneath the patient's body. The stretcher may be made of buttoned coats with strong sticks slipped through them, or it may be a board or a piece of metal. It must be rigid enough to keep the patient's body from sagging. Three men can lift a person by thrusting their arms beneath his body, holding it level. It is better to put

From *First Aid in Emergencies* by Eldridge L. Eliason (Lippincott)

The tourniquet on the arm is made of two boards bound with strips of cloth. One board presses an artery against the bone. The tourniquet on the leg is tightened by twisting the stick.

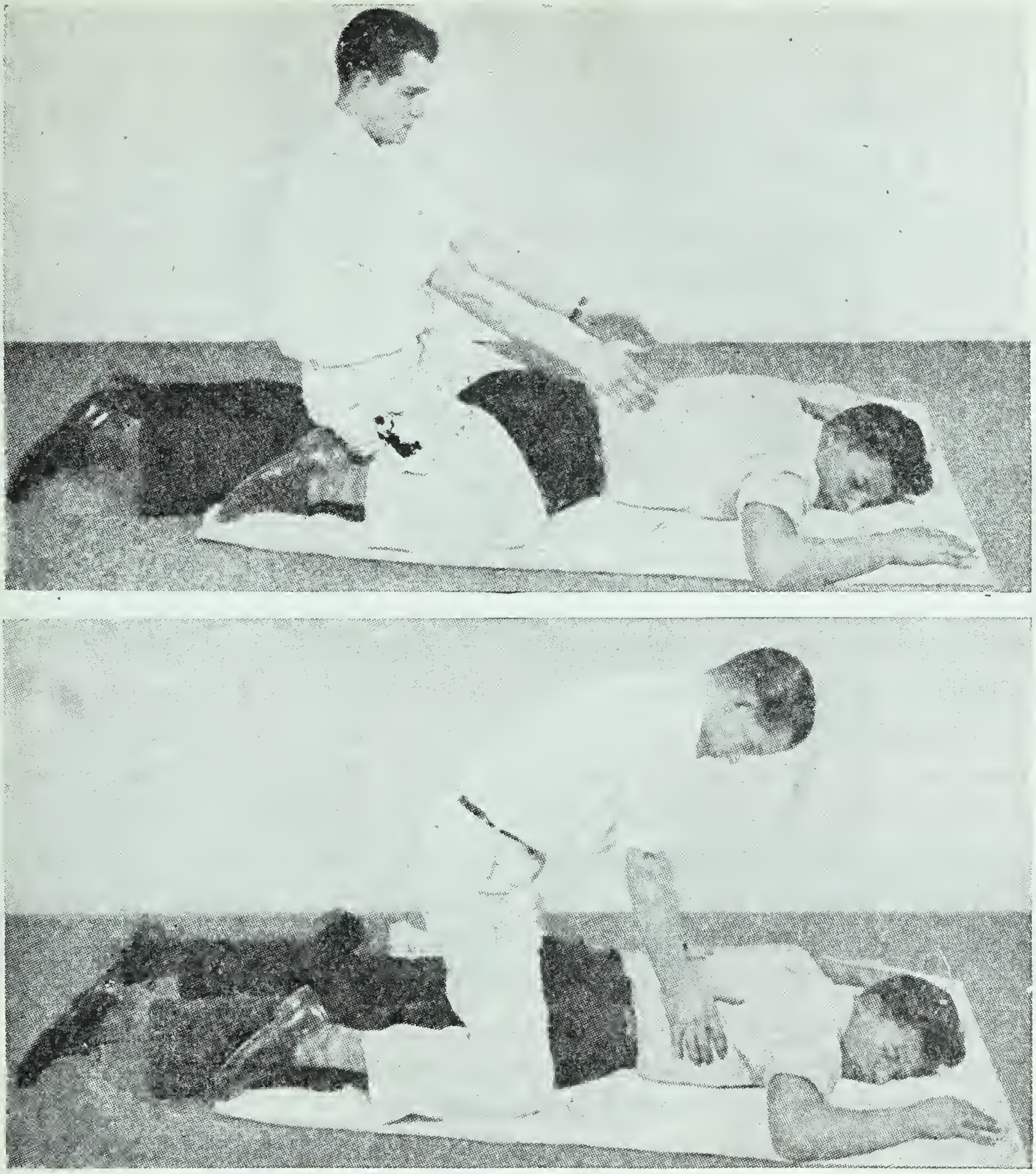
the patient flat on the bottom of a truck than in a passenger automobile. Never, under any conditions, set the patient upright in the seat until it has been determined that no ribs or vertebrae have been broken. Get the help of a doctor or first-aid specialist as soon as possible.

What should be done to treat burns? If the victim's clothes are afire, smother the fire by rolling him on the ground or by covering the fire with a rug, blanket, or woolen coat. It may be necessary to use force to do this. If the victim stands up, he may breathe flame and die. The best home treatment of burns which break the skin is use of a solution of one tablespoonful of soda in a pint of sterile water. A sterile bandage is dipped into this solution and spread on the burned area. The bandage should be kept warm and moist until medical aid arrives. If other materials are available in a first-aid kit, follow directions exactly. For burns which do not break the skin, use of a cooling ointment or clean mineral or vegetable oil is sufficient.

Never put cotton or a dry bandage on a burn which breaks the skin. Don't pull burned cloth from the wound. Don't apply iodine. Don't use any bandage that is not sterile.

What treatment is required for drowning and electric shock? In the case of a person who has lost consciousness from either drowning or electric shock, the first requirement is to re-establish breathing. It may be necessary to remove the victim from a live wire. Do not touch him until the current has been shut off or grounded on each side of him.

Lay the victim face down. Remove gum, tobacco, false teeth, or any other object from the mouth. Be sure that the



From *First Aid in Emergencies* by Eldridge L. Eliason (Lippincott)

A procedure for applying artificial respiration is illustrated. Note particularly how the hands are placed, with the little fingers just touching the lowest ribs. This operator would work still more effectively if he were sitting nearer the patient's feet and had not extended his thumbs.

tongue does not clog the throat. Bend one of the patient's arms to serve as a pillow, and rest his head sidewise upon it. Stretch the other arm above his head. Then sit astride the body. Put your hands where the little finger just touches the lowest rib. Then with your arms stiff, lean forward slowly until your weight presses upon the patient. *Immediately* swing backward, releasing the pressure.

To obtain the correct rhythm, chant, "Out goes the bad air, and in comes the good." As you say, "Out goes the bad air," press forward. Then take your hands away quickly. As you say, "and in comes the good," sit back. The operation should be completed each five seconds. Normal breathing should occur after a few minutes, but sometimes patients have been restored to life only after hours of effort. Artificial respiration, as the process is called, should be continued until the patient recovers, unless his muscles become stiffened by death.

After normal breathing is restored, treat the patient for shock.

What is the treatment for shock? Following any severe injury, the patient is likely to suffer shock. The symptoms are chilling, poor circulation, a pale or bluish color of the skin, cold perspiration, and a rapid and weak pulse. The patient should lie down, and be kept warm by use of hot-water bottles, blankets, newspapers, or any practical materials. The head should be kept below the level of the body. Stimulants are generally not needed, although some people want hot coffee. Whiskey and alcohol are definitely harmful.

What should be done for snake bite? When a snake strikes, its hollow, needle-like fangs inject poison deep into the wound. Unless the poison is removed or unless its effects are offset by antivenin, the patient will die. The directions for use of antivenin serum are included with the kit, which may be purchased complete.

The poison can be washed from the wound by causing bleeding. Since almost all snake bites occur on the arms or legs, poison may be kept out of the blood stream by placing a tourniquet above the wound. Loosen it every 10 minutes. The next step is to cut an X over each fang mark. A clean, sharp knife should be used if possible. Each cut should be one-fourth of an inch deep and half an inch long. Blood should be caused to flow from the cut for half an hour, either by use of any suction device available or by sucking with the mouth. Then treat the patient for shock.

What should come before first aid? First aid is usually required because someone has been stupid or careless. Do not ride with a driver who is reckless, careless, intoxicated,

Courtesy American Red Cross

Any boy who runs all the risks shown here needs information about first aid. He is using the knife wrong, a hatchet is always dangerous, and what about the nails?

or too tired. Do not wrestle in water. Do not swim in deep water without someone near in a boat. Do not use matches, gasoline, alcohol, electricity, or chemicals carelessly. Do not walk in places where there are snakes unless you wear heavy boots. Keep out of weeds if you are barelegged—shorts are not intended for wear in the woods. Don't put your hands in holes, on the ground, or in weeds where you cannot see. You might find a snake or poison ivy. Do your climbing on safe ladders. Do not stunt or show off.

An injured person frequently is either a fool or a victim of a fool. Even so, we should try to save his life by every possible means.

Exercise. *Write a paragraph summarizing this problem, using the following words:* shock, artificial respiration, pressure, 12 times a minute, soda, bleeding, pressure points, cut, antivenin, warm, suction, half hour, tourniquet, 10 minutes.

Science activities. 1) This activity is required of every pupil. Count off the class in pairs. Preferably let friends work together. Spread newspapers on the floor. Practice artificial respiration until the "victim" is forced to breathe because of the efforts of the pupil working. Practice to maintain perfect rhythm. Exchange places frequently.

2) Locate on yourself or another pupil every pressure point shown in the diagram.

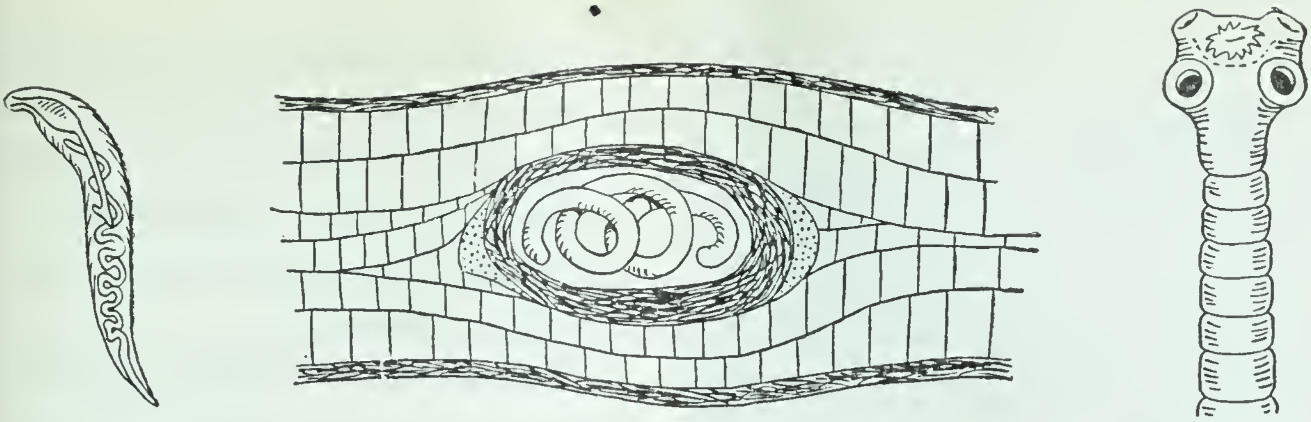
5. How do drugs influence health?

Drugs are chemical substances which may be taken into the body to kill certain organisms, such as bacteria, or to help the body in killing them. Drugs may supply materials the body lacks. Use of drugs is one of the oldest methods of medical treatment and, until recently, one of the least effective.

What are specific drugs? A specific drug is one which cures a specific (certain or definite) disease. For example, quinine is a specific drug for malaria. The parasites which live in the body and cause the disease are injured by this drug, and their rate of growth is greatly decreased. On the other hand, quinine is of no use in treating colds, for colds are caused by a different organism.

Sulphur is a specific drug for certain skin diseases of the ringworm type. Properly used, it kills these organisms almost immediately, and in a few days the symptoms disappear. Sulphur is of no use internally as a tonic, although some ignorant people still take a mixture of sulphur and molasses in the spring to "thin the blood."

As long as scientists worked to use natural drugs for cure of disease, their success was limited. The problem was to find chemicals which could be introduced directly into the body, capable of killing or retarding the growth of bacteria without killing or injuring the patient. Several years ago a chemical was developed which has value in controlling a single disease, syphilis. Recently, by using another chemical



HOOKWORM TAPEWORM

Specific drugs exist which can be used to rid the body of hookworms and tapeworms, but none exists to free the body of the trichina worm which buries itself in muscle tissue (*center*).

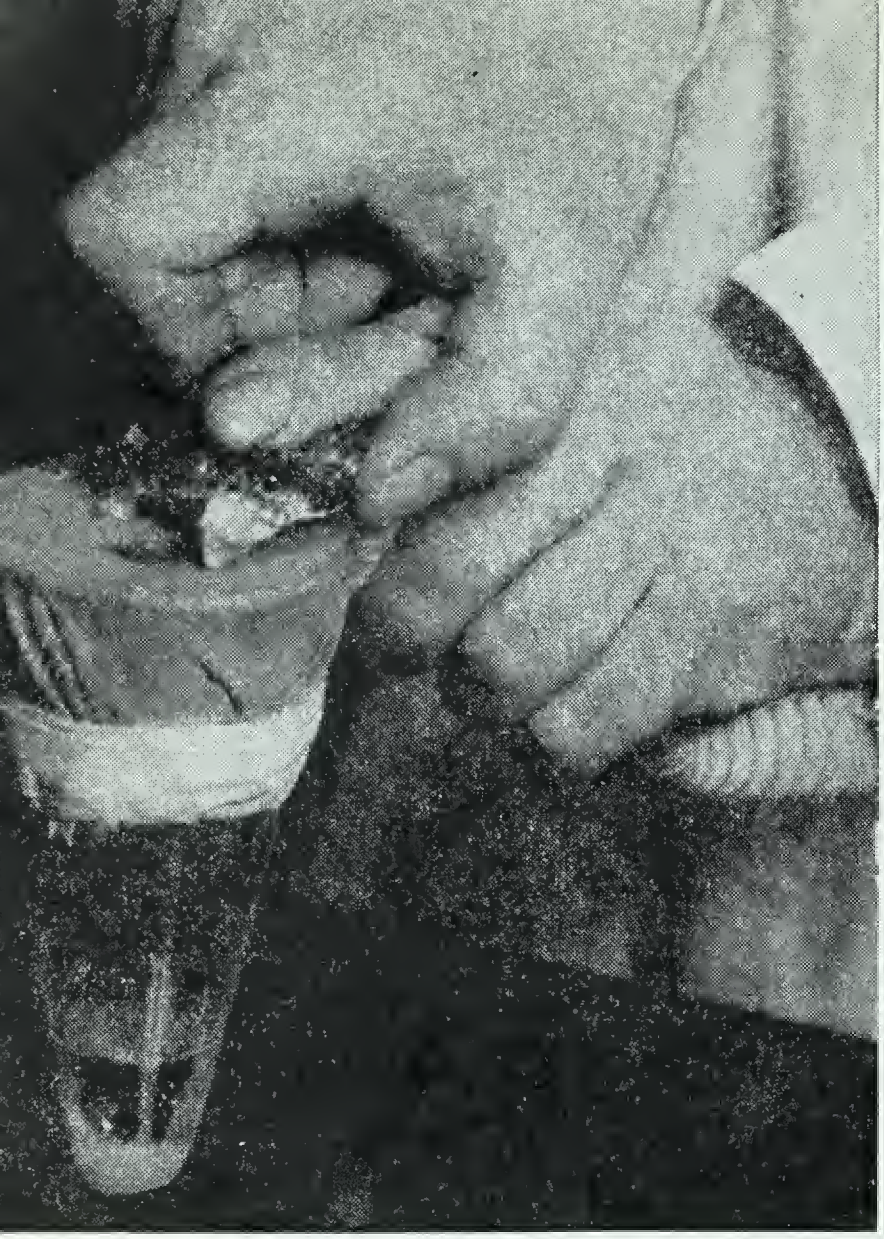
that a few years ago was a waste product in German dye factories, scientists developed a drug which offers a method of curing specifically many diseases. The new drug is called sulfanilamide [sŭl′fȧ·nĭl′ȧ·mīd].

Within three years after its discovery this drug was found to be of great value in controlling 14 diseases, most of which are deadly in their effects. All these diseases are caused by one type of bacterium—the round or coccus type. Among the diseases for which this drug has specific action are septic sore throat, scarlet fever, at least one type of pneumonia, four diseases of the reproductive organs, and several others. Other sulfa-drugs are being developed and used to cure other diseases.

These new drugs are not cure-alls, nor are they safely used by an individual without medical supervision. They occasionally cause sickness. Only a doctor can determine which sulfa-drug to use and in what amounts it is needed. Use of these drugs marks a stage in the development of curative medicine almost as revolutionary as was the discovery of bacteria.

Although other specific drugs are being developed, there are still many diseases which cannot be cured by any specific drug known today.

What are serums? A serum is a chemical similar to the antitoxins of which you have already read. A serum is often used during the progress of a disease to produce within the body an environment unfriendly to the bacteria which cause the disease. Some types of pneumonia are now being treated with serums.



Courtesy Sharp and Dohme

To make a serum for protecting against rattlesnake bites, poison is extracted from the fangs of the snake. The fangs are pressed through a sheet of rubber.

These chemicals cannot be used by the individual. In fact they are worse than worthless when used for anything but the one disease which they help to control.

What are general drugs? There are some drugs that do not cure diseases directly but in some way help the body. For example, a person may be too restless or in too much discomfort to sleep, yet the chief cure for his sickness may be rest. A drug which helps the sick person to rest thus cures him indirectly but does not cure the disease.

Two common types of general drugs are stimulants, which increase the action of the body or one of its parts, and sedatives, or narcotics, which slow down bodily action. Most stimulants are dangerous if taken in quantities larger than needed. Stimulants should be used only under the observation of a doctor, because they use up energy faster than the body normally replaces it. Sedatives have an effect opposite to that of stimulants. They, too, are generally dangerous if misused.

What are patent medicines? So-called "patent medicines" are neither patented nor medicines. The name or label of the bottle is copyrighted in the United States Copyright Office. The makers are not required to list the materials used, except to avoid using certain drugs, such as opium, strychnine, and other very dangerous substances. The Federal Food, Drug, and Cosmetic Act of 1938 prohibits making specific promises to cure a disease on the label of the container.

That the American people are in sore need of correct information on health problems is evidenced by the wide use of patent medicines. Advertisements of patent medicines reach the eye on every hand—on billboards, in magazines, and in newspapers. One sees the shelves of drugstores loaded with packages containing patent medicines. The false claims of these medicines enter our homes over the radio. It is estimated that the American people spend every year a third of a billion dollars on patent medicines.

How can this willingness of the American people to waste so much money on worthless or harmful medicines be explained? There are several factors involved. One factor is the ignorance of people concerning some of the most elementary facts regarding health. Another factor is the publicity that patent medicines receive as a result of wide advertising. When people hear an article advertised often enough, they seem to think that it must be of value, regardless of its real merit. And a third factor is that when people are sick, they become desperate and are willing to try anything in the hope of getting well.

Most patent medicines fall into one of three classes. There are the bracers, advertised for their effect as tonics. They contain a large amount of alcohol which produces a feeling of exhilaration. The sedatives depress the nerves and thus have a soothing effect. Then there is the group of patent medicines that contain those drugs advertised as cures for all sorts of diseases, ranging from cancer to tuberculosis. The broad claims of these medicines brand them at once as being fakes.

Some medicines contain such common things as sugar and baking powder, which, of course, are harmless but which are also worthless because they can have no effect in curing sickness. But unfortunately, some patent medicines contain substances which are positively harmful to the body. One radium "cure" actually contained radium and filled the bones of a man it killed full of radium. His bones contained enough radium to make light streaks on a film, when placed on a photographic plate. Many patent medicines contain large per cents of alcohol. Some people, who would be shocked at the thought of drinking alcoholic liquors, regularly take patent

medicines which contain larger per cents of alcohol than do beer or wine. Through the regular use of patent medicines, it is possible to acquire an appetite for alcoholic liquors and possibly the drinking habit. The harmful effects of alcohol in patent medicines when used in excess are the same as would result from drinking wine or whiskey.

One of the harmful results of depending on patent medicines to cure illness is that the average person does not know whether he is getting the proper treatment for his illness. Yet most people insist on treating themselves anyway. A person who cannot tell what is wrong with his health cannot effect a cure. Patent medicines are of no use even when one knows what disease he has. Yet almost half the money spent for medical care in the United States is wasted on patent medicines.

Perhaps the greatest danger involved in the use of patent medicines is not in the effect they produce on the body but rather in the feeling of false confidence which their use brings. Meanwhile the disease may be growing worse. While an ill person is wasting time on the useless drinking of flavored water, one of the deadly diseases may be gaining headway. Self-treatment of tuberculosis or cancer may be fatal.

The fact that some people who treat themselves get well proves that probably nine-tenths of all illnesses are not fatal, no matter what one does. Treatment by an unskilled person is of no value whatsoever.

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* specific drug, general drug, quinine, sulphanilamide, patent medicine, alcohol, sleep, advertising, serum, coccus.

6. How is the use of drugs related to mental health?

The subject of mental health is so complex that few doctors of medicine consider themselves authorities upon it. As you know, mental ill health may take many forms, such as nervous breakdowns, tendencies to show off, extreme sensitiveness, fear of failure, lack of self-confidence, nervous movements, violent temper, or fear of strange places. One of the

most serious effects of mental ill health results when the ill person turns to drugs to obtain sleep, to gain a feeling of vitality, or to escape from his troubles. Others less ill mentally turn to patent medicines to treat their difficulties, obtaining no real relief except through a feeling that they are doing something.

Our attitude toward those who are mentally ill must be more intelligent than it has been in the past. There is almost always a reason for mental illness, and the cause must be removed. We must learn to recognize it, in order not to be influenced by the unsound emotional and mental processes of the mentally ill.

How is mental ill health affected by alcohol? Normal people do not drink alcohol to excess, and most of them do not drink it at all. People who drink excessively do so to escape from some fear, uncertainty, or unpleasant situation. If you are influenced by others to drink, you may start a habit which will cause you, too, to develop some form of mental sickness. For the effects of alcohol on the body are such that it not only gives the mentally ill a means of escape, but it also causes changes in the

Courtesy The Traveler's Insurance Co.

The hands of a person who uses alcoholic drinks are not safe on a steering wheel. Alcohol increases the time needed to react, decreases judgment, and reduces skill—three important factors in driving an automobile.

body and in the emotional processes which produce mental ill health.

The immediate effect of alcohol is quite apparent. A small amount decreases a person's ability to be self-critical and weakens judgment. That is, a person who is typing while mildly intoxicated may think he is doing better than usual, while actually he is typing more slowly and making more errors. In the first stages of intoxication, reckless acts seem reasonable, money loses its value, and people seem different.

The second stage of intoxication involves loss of muscular control and lack of mental clearness. The gait becomes uncertain, small movements such as eating or writing become difficult, speech is confused, and judgment is so poor that acts may be committed that are completely unreasonable. In this stage, an automobile driver cannot drive well enough to remain on the road. Possibly one-fourth of all fatal automobile accidents are caused in part by the drinking driver. Immoral acts of various kinds may result from lack of normal judgment of their consequences.

The third stage of intoxication is loss of consciousness. This loss may be temporary if not too much alcohol is taken. If a sufficient quantity has been taken, death will result, just as it will from a sufficient dose of any poison.

The immediate effect of alcohol on the body is chiefly through its action on the nerves. It is related chemically to ether, which dissolves the fatty substances in certain nerves and makes them unable to do their work.

Alcohol also withdraws water from the tissues of the body, and to some extent upsets their normal functioning. The amount of upset is dependent upon the amount of alcohol taken.

While alcohol is not always the cause of mental disease, when a mentally ill person turns to alcohol to escape his problems, alcohol upsets physical health. There is a definite relationship between alcoholism and insanity of various kinds. Many drinkers never become insane but are merely incompetent to get along in the world. They are unable to remain on a job long enough to get established, cannot keep out of debt, and do not enjoy normal types of activity. Al-

cohol may cause physical illnesses and injury to the stomach, liver, kidneys, heart, and arteries.

Alcohol can easily become habit-forming. Not all who drink it will form the habit, but it is impossible to know in advance who such people are.

What are narcotics? Alcohol is generally classified as a narcotic. There are other narcotics which are less common, and still more deadly, than alcohol. A narcotic drug reduces the activity of parts of the brain. The particular effect of a narcotic depends upon the kind used. The commoner narcotics are opium, cocaine, and marijuana. They are sold in direct violation of state and federal laws. Thus anyone who has any contact with them is dealing with criminals and running the risks attached to any criminal act.

The drugs themselves produce marked permanent changes in the nervous system after a period of use. While it is perhaps possible to get rid of the habit of using these drugs, it involves a cure that is long, painful, and tedious. Death usually results within a few years from use of narcotics.

Marijuana is the drug that is most commonly sold by criminals to school children. Under the influence of this drug moral responsibility is lost, and crimes ordinarily regarded with horror seem to be normal behavior. Marijuana is commonly made into cigarettes and may be disguised as one of the standard brands. Criminals make a practice of trying to form the drug habit among children in order to have buyers for the drugs later. Never, under any circumstances, take a cigarette from a stranger or an acquaintance whose reputation you have reason to suspect.

How do sleep-producing drugs affect health? The use of sleep-producing drugs other than narcotics is largely an adult problem, yet you should know about it. When people become nervously exhausted or extremely worried, they cannot sleep easily, as can a normal, healthy boy or girl who lives and exercises regularly. There are a number of sleep producers on the market, the names of which are of little importance to you. They do produce rest temporarily, but they also cause a loss of normal habits of going to sleep. These drugs all act upon the nervous system and produce a number of rather serious ill effects.

What are stimulant drugs? There was recently a fad among college students and some high school students of taking "pep pills" before examinations, the idea being that the brain is clearer when the drug is used. This is another popular notion that does not hold true when tested experimentally. Some experiments show that definite interference with learning results from use of this drug.

Possibly the least harmful of all stimulants is caffein in a pure form. It is found in coffee, which depends for its flavors upon oils that soon become rancid and difficult to digest. Caffein is used by truck drivers who must work all night and by others who must resist sleep. Sleep, however, is not something to resist but something essential to health. Use of a stimulant to keep one awake is always bad. The body uses up its energy faster than it is replaced, and dangerous fatigue results. Tea contains a drug similar in its effect to that in coffee. A third drug of this class is found in cocoa. Have you heard advertising over your radio recommending cocoa foods to help you sleep? Their actual effect is to keep you awake. Children should not use any stimulating drug, for they need sleep even more than do adults. In one bottle of some soft drinks there is about one-half the amount of caffeine in a cup of coffee.

These stimulating drugs normally are not habit-forming. They are used to overcome a feeling of lack of interest or lack of energy that may result either from physical or mental ill health or from lack of sleep.

Does tobacco affect health? If you formed your opinion from tobacco advertising, you might believe that everyone smokes. If everyone does smoke, it is evidence of a general lack of poise and maturity. Smoking is a form of nervous habit with many people. Some psychologists say that many people smoke because they have never outgrown the infantile desire to have something in their mouths upon which to suck.

Tobacco, in spite of the advertising and fake science to the contrary, does have a certain undesirable effect upon the heart. It is irritating to the eyes, nose, throat, and lungs. It affects the blood pressure, and the flow of blood to the skin increases. Its use does seem definitely to be related to shorter

Courtesy Libbey-Owens-Ford Glass Co.

Air-line companies have rules severely regulating drinking by the pilots. When safety of plane and passengers depends upon clear thinking, alcohol is dangerous.

than average life. Whether those who smoke are more likely to die anyway is not known, but the relation exists.

Students who smoke are known to make worse grades than those who do not smoke. Whether poor students smoke to try to hide or make up in some way for their lack of ability or whether smoking interferes with thinking is not definitely known. It may be that good students are wise enough not to smoke, and poor students are easily taken in by advertising. At any rate, smoking is injurious and is related to undesirable traits.

Why do the mentally ill use patent medicines? Most of those who use patent medicines over long periods of time are suffering from mental ill health. Those who are suffering from physical ill health and are using patent medicines do not continue for long periods of time. They either die from lack of attention or become so much worse that medical care is required or get well anyway and stop taking the medicine.

There is a large class of people who enjoy poor health and use it as an excuse either to escape their responsibilities or to provide a means of centering attention upon themselves by seeming to be ill. To these people patent medicines are a welcome help. They take the flavored water, bitter drugs, and salts with the air of one scarcely able to bear up under the cruelties of life. The medicine is a valuable stage property to help them in the act of seeming ill. To such people, an attack upon the patent medicine racket is to be resented as an attack upon themselves. These people probably harm themselves only slightly, even though they help themselves not at all in overcoming mental ill health. They sometimes influence the really ill to take their worthless medicines with serious results.

Exercise. *Complete the following sentences:* Alcohol attacks a fatty substance of the —1—. It is classed as a —2— drug. Other drugs of this class are —3—, —4—, and —5—. All these appeal most to the —6— ill and increase mental ill health by injuring the —7— system. A —8— causes sleep, and after continued use, death. A —9— speeds up use of energy or delays sleep. Patent medicines are widely used by the —10— ill.

Science activities. 1) Water one plant with pure water and another similar plant with water with 1 per cent alcohol in it. Observe the results.

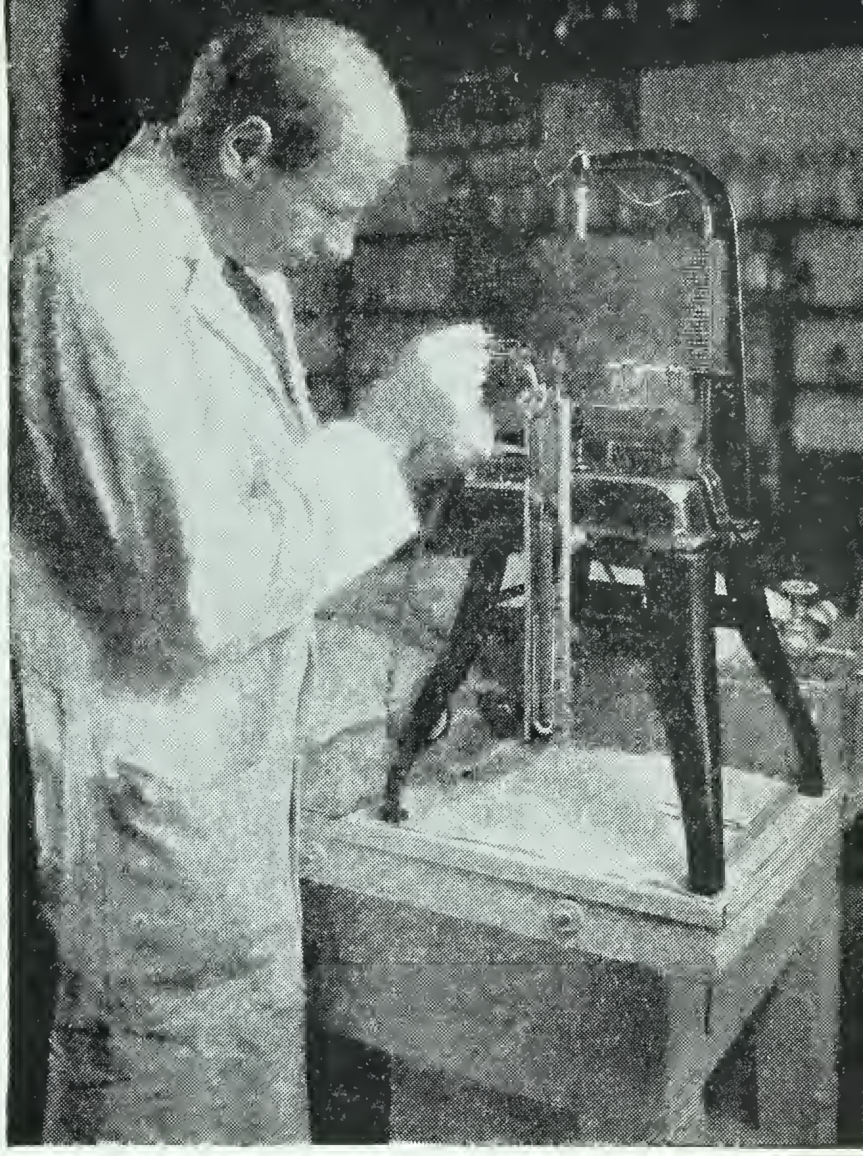
2) Search through the advertising sections of magazines and papers for patent-medicine advertising. Make a scrapbook of false, exaggerated, or foolish advertising. Include electric belts, bunion cures, methods of reducing, and so on.

7. How is modern medicine an applied science?

It is apparent that medicine has progressed far along the road toward becoming a science since the days of Hippocrates and Galen. Even so, it is difficult for us to realize even to

a slight extent how dependent the modern doctor is upon science for his diagnosis of illnesses and for their treatment.

Does medicine employ experiments? Carefully controlled experiments are common in medical investigation. In one such investigation, a cold vaccine was given to half a large group of college students. To the other half was given an inoculation of distilled water. At the end of the experiment it was found that the patients receiving the vaccine averaged 1.6 colds per person, while those who thought they had vaccine but did not had 2.1 colds per person. The effect of the vaccine is seen at best to be slight. However, the patients who had had injections of water instead of vaccine thought that they recovered from their colds faster than usual, showing the uselessness of opinion compared with measurement.



Courtesy Parke, Davis & Company

In this experiment measurements are being made of the effect of pituitary-gland extract upon the blood pressure of a dog. The pressure causes a change in the height of mercury in the U tube and moves a marker which makes a record on the drum.

In another experiment, several hundred wounds were deliberately infected with two kinds of pus-forming bacteria. Half the wounds were treated with iodine, while the other half were treated with a standard, red-stain antiseptic. Of those treated with iodine, only 24 per cent became infected, but of those treated with the antiseptic all became infected.

Such use of experimental methods is essential. Most medical experiments are not as simple as these described, but are just as well worked out.

Does medicine employ measurement? Most people who have had a medical examination have had their blood pressure taken. A cloth bag is wrapped around the arm. Air is

pumped through the bag and into a pressure gauge by means of a rubber bulb. At the same time the doctor feels the patient's pulse. When the pressure in the bag becomes high enough, the blood no longer circulates in the arm and the pulse stops beating. Then air is let out of the bag until the pulse can again be felt. The pressure gauge may be made like a barometer but with both tubes open, or it may be an ordinary spring pressure gauge. The figure used to describe blood pressure refers to the difference between the heights of the two columns of mercury expressed in millimeters at the time the pulse returns.

Another type of measurement is made when the number of white corpuscles in the blood is counted under a microscope. The presence of more than the usual number of white corpuscles indicates the presence of infection in some part of the body. Many other and complex methods of measurement are commonly used.

What aids to observation are used in medicine? You are familiar with the pictures of broken bones, infected teeth, and of the internal organs made by use of the X ray. As you know, these short waves are able to penetrate flesh easily and bone only slightly. X rays are really shadow pictures. To show the outline of soft tissues, such as the intestines, some means must be found to stop these penetrating rays. Usually a pint or so of a chalky chemical in suspension in water is swallowed. As it passes through the stomach and intestine, its progress can be studied. The condition of the organs can be recognized by a skilled observer if these X-ray pictures are studied. Instead of taking a picture, the rays may be caused to fall upon a screen which glows where the rays strike it. This device, called a fluoroscope, operates upon the same principle that is used in fluorescent lighting.

A number of ingenious devices have been developed for looking into various cavities of the body. Most of them consist of small lights and mirrors placed in tubes which are thrust into the cavity of the chest, lungs, stomach, or other organs. Such foreign objects as coins have been located by use of such a device and then removed. The interior of the stomach may similarly be examined for ulcers (raw sores).

Another device which indirectly shows the condition of the heart is the electrocardiograph. Contacts are made with the skin by use of salt water, usually on one hand and one leg. The body constantly produces weak electric currents. The current from the body is run through a very sensitive galvanometer. The galvanometer is caused to throw a beam of light upon photographic paper which is rotated upon a drum. The result is a wavy line on the paper. The heart makes five movements which show in the wavy line as five parts of the wave. If any part of these waves is too strong or too weak, information can be obtained about the condition of the heart.

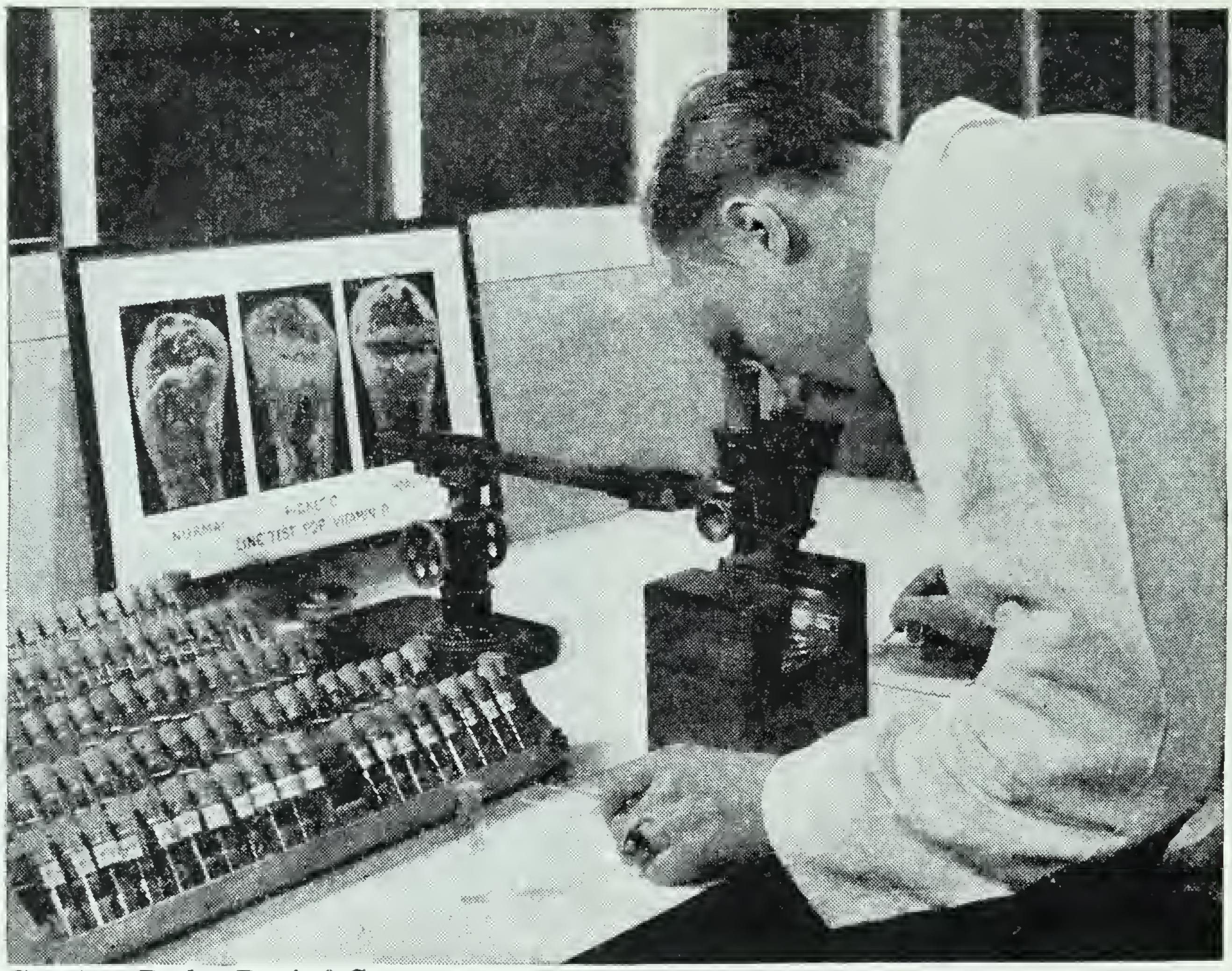
Courtesy Parke, Davis & Company

This X-ray photograph shows the large intestine greatly enlarged as the result of a diseased condition. Such a condition may result from lack of sufficient vitamin B in the diet.

A similar electrical device is used to show patterns of brain waves.

A device for examining the eye consists of a concave mirror with a hole in the center. The mirror is used to reflect light into the eye, while the examiner looks through the hole in the mirror. In this way it is possible to see the inside of the eyeball. The condition of blood vessels and the tissues of the eye can be observed directly by use of this instrument.

A simpler device is the stethoscope, which consists of a funnel-shaped tube connected to two branching tubes which are held against the ears of the listener. By placing the funnel over the heart or lungs and listening to the breathing and heart beat of the patient, a trained observer can detect unusual conditions. By thumping upon the chest, it is possible to detect the presence of fluids in the chest cavity if any are present.



Courtesy Parke, Davis & Company

The strength of a vitamin preparation is being tested by study of bones of test rats. The microscope shows how much lime the bones contain, compared with bones of rats fed a standard vitamin diet.

The microscope is used constantly in studying tissues to discover what is not normal.

Are chemical tests used? The most common chemical test used by doctors is for the discovery of sugar in the urine. This condition is found in patients suffering from diabetes. The test is similar to the test for any simple sugar—that is, a solution similar to Fehling solution is boiled with a sample of the urine. Presence of sugar is indicated by a red color.

Chemical tests of the digestive juices are sometimes advisable. Other tests consist of measuring the amount of carbon dioxide a person breathes out during a measured interval of time. The amount of carbon dioxide indicates the rate at which food is being oxidized in the cells. In certain illnesses food is used much faster than is normal, while in other diseases the rate is lower than normal.

Is study of bacteria used? Cases of pneumonia, sore throat, and many other diseases are detected by examination

of bacteria under a microscope. The usual procedure in checking sore throat is to collect bacteria from the throat on a cotton swab, which is then immediately sealed in a tube and taken to a laboratory. At the laboratory the swab is brought into contact with a sterile culture medium. The culture is put into a warm incubator for a few hours to obtain bacteria for examination. If no dangerous bacteria are found, the report is negative. If they are found, medical treatment is begun.

The doctor knows, when he has made a proper diagnosis, whether he should start treatment or whether the patient will recover without aid. Doctors know because of their familiarity with disease how to recognize many illnesses as soon as they see the patient. You must not expect every medical call to result in trying out every experimental device known to science. Yet it is comforting to know that there are many ways of using scientific methods to protect us from serious illness.

Demonstration. How Is Pressure of a Gas Measured?

What to use: Glass tubing, rubber tubing, mercury, burner, metric ruler, funnel, rubber bands.

What to do: Make a U-shaped glass tube about 15 inches long, with the arms about 1½ inches apart. Fill the tube about one-third full of mercury by use of the funnel and a rubber connector.

Attach the manometer tube you have made to the ruler in an upright position.

Connect a piece of *sterile* glass tubing used for a mouthpiece to one end of the manometer tube, and blow into it. Let another pupil read the *difference* in the level of mercury in the two arms.

What was observed: Can all pupils blow with equal force? How many pounds per square inch does your reading correspond to?

What was learned: How does this demonstration relate to blood-pressure measurement?

Exercise. *Complete the following sentences:* A safe antiseptic for wounds is —1—. The blood-pressure gauge contains —2—. When one is infected, the number of —3— in the blood increases. X rays are used to throw a shadow on a screen called a —4—. The screen changes X rays to visible —5— rays. The weak current from heart beats is measured by a sensitive —6—. A gelatin

Courtesy Atchison, Topeka & Santa Fe Ry.

The Pueblo Indians lived on a diet that seems very simple compared to ours, but they survived on it. They baked bread in the dome-shaped clay ovens. Did they use highly advertised drinks, breakfast foods, and canned goods to be healthy?

plate upon which bacteria are grown is called a —7—. Sugar in the urine indicates —8—. Bacteria are placed in an —9— to make them grow faster.

8. How can we avoid unfounded beliefs regarding health?

There are many unfounded beliefs which may lead to acts which affect our health. Some of these beliefs are leftovers from the days of unscientific medicine, some are deliberately created by advertisers, and some are the result of faulty application of sound scientific discoveries.

What is the truth about food fads? You have read many times that you should eat some particular food to be healthy. As a matter of fact, for a person past babyhood, there is not a single food in the whole world which is indispensable. Some foods do, as you know, provide a greater variety of essential food materials than do others. But every essential food material is found in a great variety of foods. The Asiatic who eats his diet of fish, rough rice, and vegetables is about as healthy as a person in the United States who eats over-processed and much more expensive foods.

There is no special virtue in any food. While orange juice, grape juice, milk, lemons, meat, and whole grains are excellent foods, none is so essential that sickness results from not using one or more of them. Many foods advertised as health foods are actually difficult to digest, lacking flavor, and much more expensive in proportion to the calories, vitamins, minerals, and proteins they contain than are everyday foods.

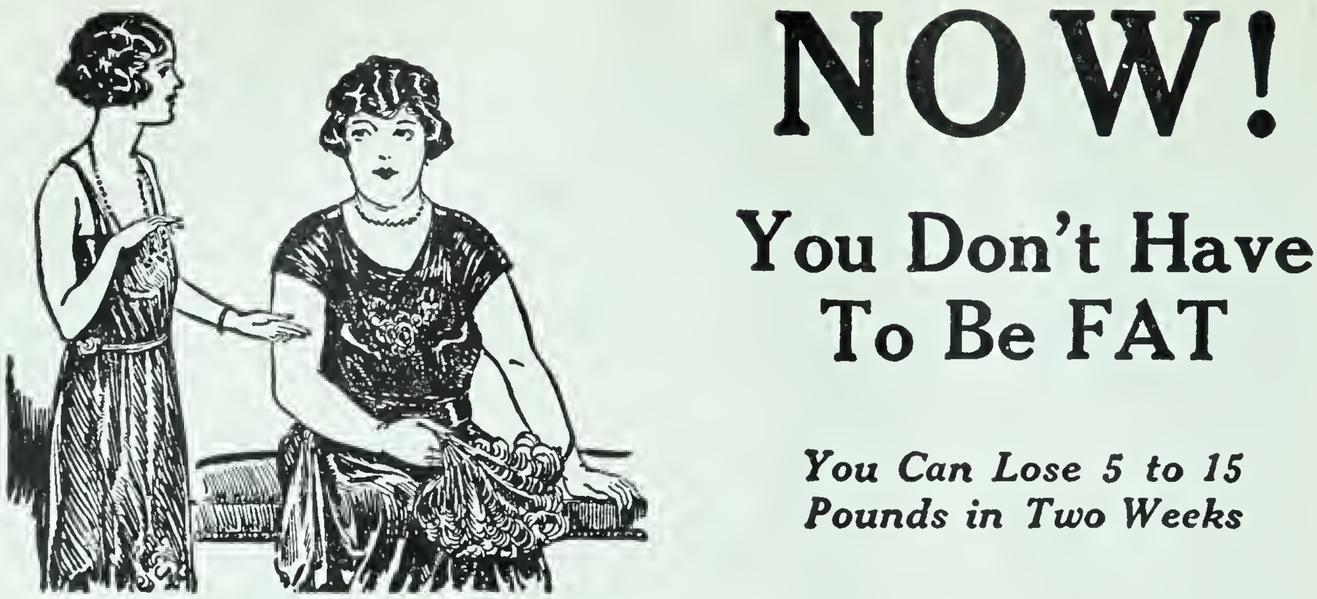
Food fads are recommended for various supposed reasons. One is to give greater charm because of improved health, beauty, or vitality. Food is necessary for these things, but no one food is much better than another for producing these effects. In fact, a balanced diet of many common foods is better than a limited diet of any kind, no matter how excellent the foods may be.

Special diets for reducing weight are sometimes recommended by newspaper writers, radio speakers, and other unqualified persons. The only right way to reduce weight is to reduce the intake of calories, and the only way to do it safely is to do it slowly while eating foods to make an adequate diet for health.

Why worry about elimination of wastes? The most profitable source of income from patent medicines, next to the beauty preparations' racket, is that of selling laxatives. Few people need laxatives to produce normal elimination of wastes. Laxatives upset the normal processes of the digestive system by one of three methods. Oils hurry foods along the digestive tract faster than the digestive juices can act on them. A mineral-oil salad dressing on a green salad hurries the food along so fast that the body cannot absorb the vitamins from the salad. Salts acting by osmosis withdraw water from the digestive tract and prevent the absorption of food. Certain drugs stimulate or irritate the digestive tract in various ways, hurrying the materials along at an unnatural speed.

Most people can have normal elimination merely by eating a balanced diet including fruits and vegetables, by forming regular habits, and by drinking reasonable amounts of water.

Contrary to popular belief, exercise seems to have no effect on elimination. Use of bran and other harsh roughage



Not many years ago advertisements like this appeared frequently in newspapers and magazines. Today this ad looks funny, not only because advertising has improved but because dangerous drugs are regulated by law.

is definitely injurious and would probably be discontinued if advertising did not keep its use before the people.

Laxatives are especially dangerous to one suffering from an attack of appendicitis, for the irritation of the intestine may cause the appendix to burst, throwing infection into the lining of the body cavity. This infection may cause death. Never take a laxative for a stomach-ache.

How can we select good medical care? There are many unfounded beliefs about the efficiency of so-called methods of healing. Any reasonable person can decide for himself which systems are not founded on true scientific procedure.

You know many of the procedures depended upon by doctors of scientific medicine. Such a doctor is familiar with the use of scientific instruments and methods and has studied most diseases which people may have. When a patient comes to such a doctor, the doctor immediately makes a diagnosis of the illness by use of his skill and experience. He tries to learn all he can about his patient. Then, when he has found the cause of the disease, he fits treatment to the disease and to the patient. For example, there are many causes of sore throat, and treatment which will produce an immediate cure of one kind may be useless for another. A scientific doctor knows what treatment to use. If the illness is one from which the patient will recover by natural means, the doctor makes the patient comfortable and awaits the natural cure.

If no cure for the disease is known, the doctor makes every attempt to aid body defenses against disease.

Unscientific medicine, on the other hand, does not attempt to discover a different cure for each disease. Instead, most such systems depend upon one type of treatment for all diseases. For example, every patient may be treated with ultraviolet light, or pressure may be exerted upon the feet or other parts of the body in a supposed attempt to cure illness. Any doctor who has only one system of treatment for all diseases is a quack—a fake who pretends skill he does not have. Such doctors are especially pleased to see a patient with a disease from which he will recover naturally, for the doctor then can apply his treatment and claim credit for the cure. But when the patient has a fatal illness, the quack doctor rarely claims responsibility for the death.

Selection of good medical care is of great importance. Only half the people in this country have any medical care at all.

Why are unfounded beliefs untrue? In the following table are several unfounded beliefs, with an explanation of what is considered to be the true situation. You should be able to add to the list yourself.

Unfounded beliefs	*Explanation*
Kidney disease is the cause of most backaches.	Backaches are oftenest caused by poor posture or flat feet or both.
A drunk person is not easily injured by falling.	Drunkenness is a major factor in causing deaths by falls.
Playing violent games makes one healthy.	Only the healthy can play violent games.
We dig our graves with our teeth (by overeating).	As many Americans are undernourished as are overweight.
Cold baths prevent colds and make you healthy.	Bathing has little relation to health.
Outdoor living will prevent tuberculosis.	Many tuberculosis patients are outdoor workers.
A clean tooth never decays.	Ordinary methods do not clean teeth.
Shaving makes hair grow.	People shave because hair grows.

Unfounded beliefs	*Explanation*
One should take medicine to prevent acid stomach.	The stomach is normally acid.
Salt and meat cause high blood pressure.	Salt and meat are necessary in a balanced diet.
1) One should sleep with the windows open. 2) Night air is dangerous.	We should sleep in a warm, well-ventilated room, but warmth is as important as air circulation.
Many people are cured by miracles.	The mentally ill may sometimes suddenly abandon the "act" of illness.
One can cure himself of most illnesses.	He who hath himself for a doctor hath a fool for a patient.
All outdoor air is pure.	Air above cities contains smoke, dust, and fumes, reducing the value of sunlight.
One needs a yearly sunburn.	Sunburn is often dangerous.
The best way to lose weight is to exercise.	Exercise improves the appetite and may cause gain in weight.
If a sick person fights his sickness, he will recover.	The ability to fight depends upon the amount of vitality left.
Most people need a special diet to remain healthy.	Most people can eat almost any kind of food that is fit to eat.
Tight hatbands cause baldness.	Baldness is the result of inheritance.

Exercise. *Complete the following sentences:* —1— food is absolutely necessary for health. The way to reduce weight, if it is necessary, is to reduce intake of —2—. —3— oil should never be used in salad dressing. Use of laxatives in an attack of —4— may cause death. —5— medicine depends upon one treatment for all illnesses. There are more than 30 kinds of —6—. One should not play football unless he is —7—. Sunburn is often —8—.

Science activities. 1) Make a list of unfounded health beliefs common in your community, and explain why they are unfounded.
2) Find advertisements for fake health systems, and explain why they are unscientific.

9. What health habits must you form?

No amount of reading about health will make you healthy. You are the only person who can form your own habits.

The way to form a habit is to make up your mind what habit to form, then to follow it without any exception. Put a list of goals you wish to achieve on your dresser mirror or on the bathroom wall. Then never fail to work for them. Do not expect complete success in a few days.

Can food make us healthy? Get up in the morning in time to eat a good breakfast of at least 600 calories. Check every day to know that you are getting a balanced diet. Learn to eat a new food every month.

Take time to eat, and go to the table in a happy mood. Do not let any upset interfere with the pleasure and benefits of eating. Do not argue or tell of unhappy events at the table. While it is safe to drink water at meals—as much as you want—do not drink with food in your mouth. Washing down food prevents the saliva from beginning the digestive process. Watch your table manners, for good manners lead to a relaxed and happy state of mind. Poor manners lead to "gobbling," touching food with the hands, and a feeling of inadequacy.

When you eat between meals, do not fill up on sugar or candy. Eat fruit, bread and butter, milk, and other foods needed to balance your diet. If you are overweight, do not eat between meals. If you are underweight, force yourself to eat more.

Do you need rest? You are still growing. You need from 8½ to 9½ hours' sleep every night. On week-end nights arrange your parties to get home at a reasonable hour. Do not lie awake in bed, but let yourself relax and go to sleep immediately.

Keep the air fresh in your bedroom, but do not let the temperature fall below 60 degrees if you can avoid it. Use enough covers to keep warm, but not enough to make you toss about. Do not let the room get so cold that you must bury your head under the covers.

Rest during the day. If you are underweight, rest is almost as necessary as food to build up your body. When you rest, really relax. Do not kick, tap with your fingers, or talk.

Do you need exercise? In most schools only two periods of gymnasium are offered each week. This leaves five days each week in which you must provide your own exercise.

Courtesy Great Northern Railway

While it is a thrilling adventure to scale a mountain, one must be in excellent physical condition before attempting it. No strenuous sport is safe without training for it.

Any kind of play is better than none. If you are large and vigorous, football, basketball, and other strenuous sports will not harm you. If you are underweight, you should attempt something less strenuous.

Wrestling is an excellent body-builder for boys. Boxing is good only if the head, particularly the ears and nose, are protected. Diving is not a good sport, for the sudden pressure of the water forces bacteria into the ears, nose, and sinuses of the head. Swimming in clean water is one of the best sports.

Girls at 14 are in particular need of physical exercise. It may be that one cause of the greater number of tuberculosis cases among girls than among boys is that girls do not exercise enough to build up their chest muscles nor do they become tired enough to sleep nor hungry enough to eat. Girls can take part in almost any game they get a chance to play.

Setting-up exercises are beneficial only if practiced regularly. Knee-bends, push-ups, body twisting exercises, bicycle riding while lying down, and other exercises of the body muscles are of value. Occasional violent exercise without being in condition for it is definitely harmful, however. Do not start an exercise program unless you have determination to keep it up.

Do teeth need care? The average girl has nine cavities

Courtesy U. S. Public Health Service

If you have visited your dentist twice a year since you were as small as this lad, if you have watched your diet carefully to insure enough milk and vegetables, and if you have brushed your teeth regularly, the chances are that as an adult you will have sound teeth.

of the teeth and the average boy has seven at the age of 18. Careful brushing of the teeth and reducing sugar in the diet may help reduce this number. The most important thing to do, however, is to go to the dentist regularly and have cavities filled as soon as they start. Otherwise, the cavities become large and the tooth is lost.

Why should you wear enough clothes? Exposure is a major factor in reducing the resistance of the body to disease. Yet boys often go bareheaded in freezing weather. Girls leave their legs bare. Many boys and girls do not try to keep their feet warm and dry. Children walk along in cold weather with coats open. Such chilling may not seem to produce immediate illness, yet if any illness is approaching, the results will be much worse if the body has been recently chilled.

Do shoes affect health? Wear shoes that fit. The small bones of the feet must support the entire weight of the body, and they are easily forced out of normal position by ill-fitting shoes. Many children have flat feet, crooked toes, and other foot deformities. Badly fitted and poorly made shoes cause a large proportion of these deformities. The poorly selected, high-heeled shoes worn by some girls are a handicap to healthy play. Because they cannot run in the shoes they wear, such girls pretend to be too "ladylike" to play active games.

Why should you stay home when ill? When you are really ill, no school or other work is important enough to cause you to go out of your bed. Staying home and in bed a day at the right time may prevent a long period of illness and will prevent infecting your friends. A bad cold is a poor present for your best friend.

Why should you keep clean? Cleanliness generally has less effect on your physical health than on your mental health. However, thorough and careful cleaning of the hands and nails before meals is essential for physical health. The advantages of being clean otherwise are chiefly mental. No person can have confidence in his contacts with other people if his hands and nails are dirty, if his skin is unclean, or if his body is giving off odors of perspiration. (At the time of maturity, the odors of the body increase in strength.)

Boys are frequently careless about details of cleanliness. A few minutes' care produces much improvement in appearance. Boys usually must begin shaving about the age of 14 or 15. Obtain a razor which takes double-edged blades, an old-fashioned shaving mug and brush, and a cake of shaving soap. These are both cheaper and more efficient than elaborate razors and brushless creams. Work a hot lather on the face and leave it for four minutes. Then wash this lather off in hot water, and put on new lather. Shave with a sharp blade.

Girls may remove underarm hair and hair from the legs by the same method. Do not try to shave until the soap has had a chance to soften the hair, for otherwise the razor will cut tiny holes in the skin.

Girls usually are dainty in keeping clean. But girls do not

like to take showers after exercise because of the chance of getting the hair wet. A rubber cap solves this difficulty, and a shower prevents unpleasant body odors and soiling clothing with perspiration.

Pimples often trouble teenage boys and girls. About half the cases of pimples may require medical treatment. At least half, however, can be gotten rid of by absolute cleanliness. Wash the face thoroughly with hot water and a heavy lather of soap before each meal and at bedtime. Tincture of green soap (your druggist has it in stock) is better than ordinary soap for removing excess oil.

Ewing Galloway photo

It is important to have fun! Boys and girls who know how to enjoy themselves in the company of others are building a good foundation for continued mental health.

Why should you be happy? Get in on one social activity a week. Do not take part in too much social activity. If you are frequently in difficulties with your parents and teachers, take a different attitude, and adopt normal behavior. "Problem children" are building a foundation for mental illness later in life and need help to live normally. If you are in a gang that is in difficulties, find new friends.

Be friendly, and speak to others whether they speak or not. Learn to sell yourself as a good companion. Do not wait for others to make friends, for they may be too shy. Do not become discouraged, for making friends requires practice and skill.

Learn to do what your friends like to do. Playing games—both sports and house games—dancing, singing, and all sorts of social activities help make contacts with others and are of value in themselves. Don't be goody-goody or try to show off. Both show lack of social skill, and a not-quite-normal attitude toward others. Don't loaf at the corner

store, or go to movies too often. Develop more worth-while activities.

Remember, cold, fatigue, and malnutrition prepare the body for disease. Contact with bacteria produces the disease. These are factors you can control. If you really want to be healthy, you will control them.

Exercise. *Select from this problem the health habits that you need to develop. Make a list of them on a large card which you can display in your room at home as a constant reminder to improve your habits. Do not list more than five to eight habits at a time. Read the problem carefully to be sure that you select the most important habits first.*

A Review of the Unit

Maintaining good health is achieved by efforts in three directions. The medical profession investigates causes of illness and works out methods of controlling them. Among these methods are surgery, vaccination and inoculation, use of drugs, and use of other scientific methods. The individual has the responsibility of maintaining good body condition by eating an adequate diet, by getting enough sleep, by cleanliness, by avoiding contact with sick people, and by forming good health habits in general. The community has the responsibility of providing a pure water supply, inspecting food supplies, providing medical care for those who cannot afford it, and in many other ways caring for its citizens.

The relatively great success of modern peoples in preventing great epidemics, as well as avoiding the general suffering from sickness in many forms, depends upon the cooperation of all three agencies: the medical profession, the individual, and the community. None of these can take over the work of the others and hope to succeed.

An exercise in thinking

Match the principles and related ideas, according to the directions given in the review at the end of Unit I.

A. Many diseases are caused by plants and animals which live within the body.

B. Immunity is acquired when the body overcomes a disease or when antitoxins are placed in it.

C. The community must provide pure water, inspect food, and dispose of sewage.

D. The most certain way of preventing illness is to avoid bacteria.

E. Specific drugs assist the body in overcoming certain diseases.

F. Drugs may upset normal functioning of the body.

G. Cold, fatigue, and malnutrition prepare the body for disease.

H. Bacteria may be killed before they cause disease.

I. A person who is mentally ill cannot carry on ordinary activities necessary for normal living.

List of related ideas

1. One should wear a hat in cold weather.
2. Ether produces unconsciousness.
3. Some types of pneumonia are cured by sulfanilamide.
4. Tuberculosis is caused by a bacillus.
5. Kissing a person who has tuberculosis is dangerous.
6. Typhoid fever can be prevented by inoculation.
7. Proper sewage disposal prevents illness.
8. A cut should be treated immediately with iodine.
9. Athlete's foot is caused by a fungus.
10. Quarantine prevents spread of contagious disease.
11. Smallpox is best controlled by vaccination.
12. More than half the patients in hospitals are mentally ill.
13. A stimulant causes the body to use energy faster than it is replaced.
14. The best guarantee of clean food is strict governmental supervision.
15. The toxin-antitoxin treatment prevents diphtheria.
16. Lister cleaned his surgical instruments in carbolic acid.
17. A person who has had scarlet fever cannot have it again.
18. Every ninth-grade pupil needs about nine hours' sleep.
19. The sulfa-drugs are especially effective against the coccus group of bacteria.
20. Bacteria of typhoid, dysentery, and cholera are carried in water.
21. Windows and doors should be screened to keep out flies.
22. Alcohol is a narcotic drug.
23. Alcohol is used by some people to escape their fears.
24. One should never drink water from a roadside stream.
25. Trichina is caused by a worm parasite.
26. Children constantly in difficulties in school may need medical treatment.

27. Quinine is used in treating malaria.
28. Girls should protect their legs in cold weather.
29. Cities have a right to abolish use of outdoor toilets.
30. Air in hospitals is purified by ultraviolet light.
31. Alcohol weakens resistance to tuberculosis.
32. Young babies should be kept at home.
33. Insulin controls use of sugar in diabetes patients.
34. Patent medicines are usually not taken by the physically ill for long periods of time.
35. Never call on a friend sick with a contagious disease.
36. Chlorine is used in purification of city water.
37. Underweight children are more frequently ill than are children with normal weight.
38. Special diet fads usually cause harm if followed for long.
39. Pus formation is caused by bacteria commonly found on the skin.
40. Milk handlers are required to have a license in many cities.

Some things to explain

1. At about the age that many boys go into training for athletics, many girls enter into late-hour social activities. Which is the safer and better life? Why?
2. Why did modern medicine have to await development of the sciences of chemistry, bacteriology, and physics?
3. What is the chief danger in using patent medicines?
4. What are some of the useless methods advertised for reducing weight?
5. In what ways can communicable diseases be controlled better by the community than by the individual?
6. What habits are harmful to health?
7. Of what value are the various tests for immunity to certain diseases?

Some good books to read

Adams, S. H., *The Great American Fraud*
Compton's Pictured Encyclopedia
Cramp, Arthur J., *Nostrums and Quackery and Pseudo-Medicine*
Crisp, Katharine B., *Be Healthy*
De Kruif, Paul, *Hunger Fighters*
First Aid Textbook, American Red Cross
Haggard, H. W., *Devils, Drugs, and Doctors*
Hill, J., *Germs and the Man*
Mayer, B. B., *Your Germs and Mine*

Payne, George E., *The Menace of Narcotic Drugs*
Smith, G., *Plague on Us*
Swimming Pools and Other Public Bathing Places, American Public Health Association
World Book Encyclopedia
Zinsser, Hans, *Rats, Lice, and History*

Some interesting motion pictures

Disease Carriers. De Vry (*16 silent*)
Body Defenses Against Disease. Erpi (*16 sound*)
Forming the Habits of Health. National Motion picture (*16 silent*)
Contacts. Hennepin County Tuberculosis Association (*16 sound*)
Learn and Live—Value of First Aid. Experiment Station, Pittsburgh, Pa. (*silent*)
Pay Off. Y.M.C.A. Motion Picture Bureau (*16 silent or sound*)
Contamination of Drinking Water by Back Siphonage. Minnesota Department of Health (*16 sound*)
How Plants and Animals Cause Disease. Bray (*16 silent*)

Some related lantern slides

Health. Keystone View Co.

Courtesy Caterpillar Tractor Co.

UNIT TEN

HOW HAS SCIENCE IMPROVED TRANSPORTATION?

SINCE the beginning of time man has longed for means to escape from the limitations of his surroundings. We learn as children the stories of the seven league boots, the flying carpet, and the flying shoes of Mercury. These tales and many others are the daydreams of ancient peoples woven into stories which permitted them to escape, in imagination at least, from their own commonplace surroundings.

We can understand the story of the man who invented wings and fastened them to his body with wax. Although he was able to fly, he left the earth so far behind that the heat of the sun melted the wax, causing him to fall into the sea and drown. This story shows not only the desire to fly, but the realization that the dream was one impossible to fulfill. But we know that the Greeks and other ancient peoples could only dream of rapid transportation because no beginning had been made in the use of simple machines.

Today children and grownups still thrill at the sight of a giant air liner winging its way through the sky to a city across the continent. In our minds there stirs a faint feeling of the same desire to fly, to escape, to see the world, that stirred the hearts of the ancient Greeks who invented the myths.

We have many advantages that the Greeks did not enjoy. Where they could only dream of flying, we can do it. Where they told stories of magic chariots, we ride in them. Can you imagine the excitement that would have resulted if someone had driven a new automobile down the streets of Athens in Aristotle's day?

Unfortunately, there are difficulties involved in actual flying, riding in automobiles, and operation of trains that did not trouble the minds of the people who first told the marvelous stories. They did not know of inertia or of the fact that friction changes mechanical energy to heat. They did not have to buy gasoline to operate their imaginary magic carpets. We have earned our rides the hard way, not by daydreaming but by investing, working, experimenting, and developing new skills to make modern transportation possible.

1. What resistances must transportation overcome?

All the types of machines, streetcars, busses, airplanes, trucks, and trains which are used in transportation encounter certain forces which resist their motion. These familiar forces are gravity, friction, inertia, and air resistance. Every transportation device must be designed to overcome these forces, in addition to offering convenience, comfort, safety, and economy of operation.

How does friction resist motion? All machines used in transportation have moving parts, and wherever parts move against each other there is friction. The wheel was probably the first device used in overcoming friction. The problem of attaching a wheel to an axle must have been difficult for primitive man to solve.

Friction is decreased by smoothing the surfaces which move against each other. The polished surfaces of streamliners and the shining bodies of airplanes contribute to overcoming friction. Inside the machines, bearings of smooth metal have replaced the rougher surfaces used in earlier machines.

Ball bearings and roller bearings are used to provide rolling instead of sliding friction. New types of lubricants, made of oils, soaps, metals in suspension, and other chemicals reduce friction. We have spent billions of dollars in building smooth roads. It would cost more than 15 billion dollars to replace the roads now in use, exclusive of city streets.

How does gravity resist motion? Gravity offers resistance to all uphill movement or movement away from the surface of the earth. The airplane not only must overcome air resistance but must constantly maintain its own weight against the pull of gravity. Every object not supported falls with an acceleration, or pickup, of 32 feet per second. That is, if an airplane failed to support itself but fell like a rock, it would be dropping at a speed of 32 feet per second at the end of a second.

When a road passes over a hill, the load and vehicle must be lifted against gravity to a distance equal to the height of the hill. Even small bumps in the road make it necessary to

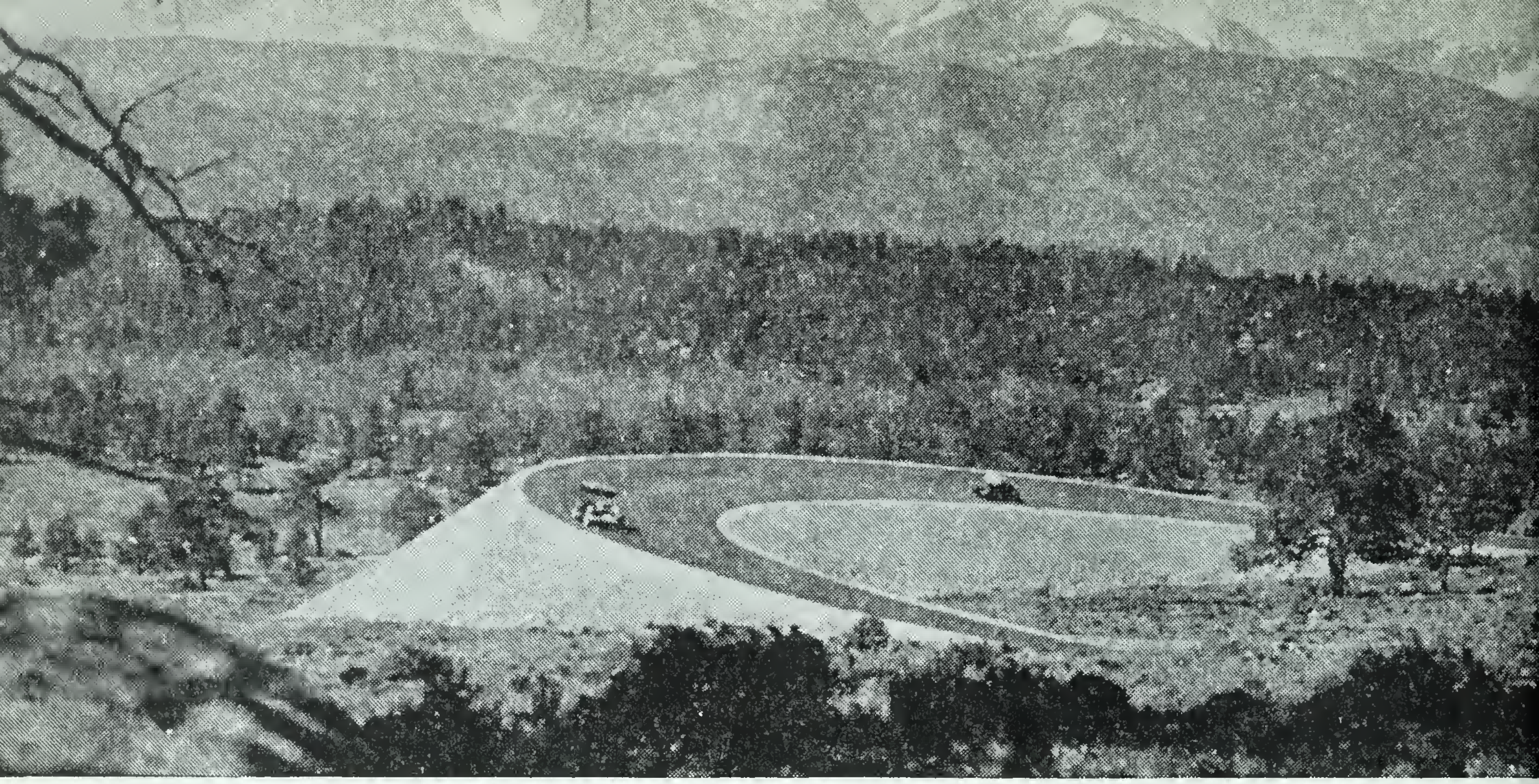
Courtesy Great Northern Railway

This heavy freight train must overcome considerable inertia to start or stop. Even on slight grades in mountains, gravity must be overcome.

overcome gravity. A heavily loaded truck, in passing over a series of bumps, uses enough energy to lift the truck to the total height of the bumps. The jolting of the vehicle and its load as it drops off the bump wears out the machine more rapidly than occurs on smooth roads. It is estimated that smooth concrete roads permit operation of trucks for about 60 per cent of the cost of trucking on rough gravel roads.

How does inertia resist motion? Inertia is the tendency of an object at rest to remain at rest or of an object in motion to remain in motion in the same straight line. When you start an automobile, energy must be supplied until the inertia of standing still is overcome. The energy then is stored in the moving automobile as kinetic energy. When you are required to stop, the kinetic energy is changed to heat by the brakes and friction of the parts of the automobile.

The change in speed of an automobile, starting from a standing position and increasing to its highest speed, is called acceleration. The rate of acceleration, or pickup, is in proportion to the force used. Because in city traffic it is necessary to overcome inertia quickly, it is desirable to have powerful, expensive engines in automobiles. One can obtain 15 to 25 miles per gallon of gas on the highway but only 10 to 15 miles per gallon in the city.



Courtesy U. S. Bureau of Public Roads

To overcome inertia, a curved road is banked. The motion in a straight line is changed into motion around the curve in part by the force of gravity and in part by friction. What would happen if the driver should fail to make the turn?

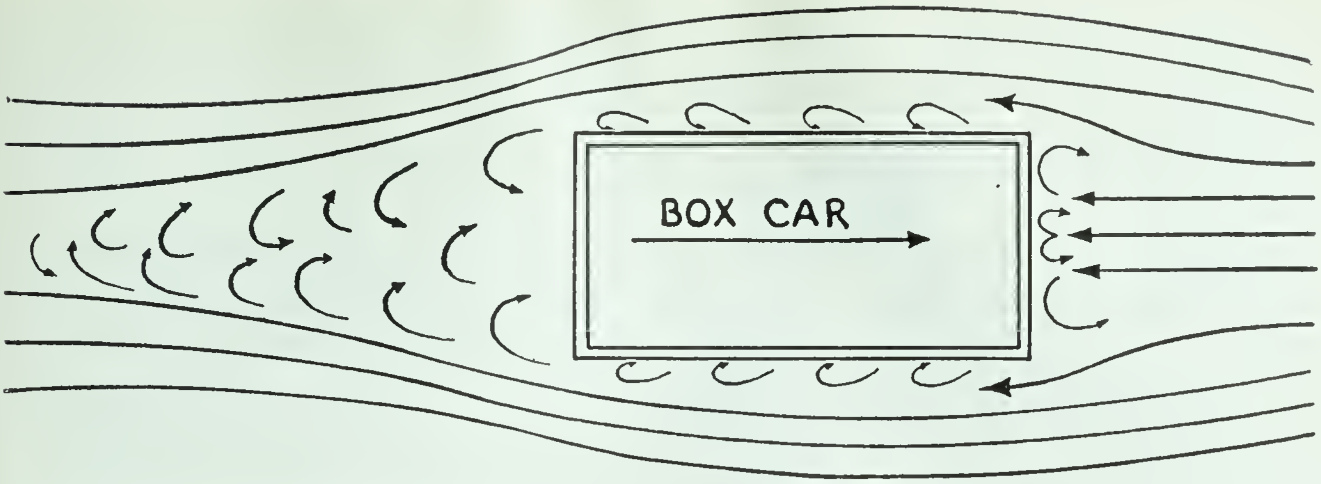
Trains traveling at high rates of speed and weighing many times more than an automobile, have much kinetic energy. Because large amounts of energy are lost every time a train stops, train schedules are arranged to require few stops. Lightweight trains are replacing heavy trains for local traffic.

Inertia of the air makes it possible for airplanes to fly. The air resists motion for an instant, which provides the resistance necessary for the wings and propeller to act against.

The inertia of a body in motion is in proportion to its weight and to the square of its speed.

The common pendulum shows very well the problems of acceleration, gravity, and inertia. When you support a weight by a cord, the weight stands still. When you put a certain amount of energy in the weight, it swings upward and overcomes gravity until the energy is stored. Then it swings downward, increasing in speed until it reaches the lowest point the string will reach. Gradually, on the upswing the speed decreases, and the weight stops and swings back through its former positions in reverse order.

Because inertia causes objects to travel in straight lines, we try to make our curving roads turn gradually. Not only is a straight line the shortest distance between two points,



This diagram shows the eddies of air along the sides and at the back of a moving boxcar. The air resistance increases rapidly as the speed increases.

but it is also the safest. Any vehicle resists being turned with a certain amount of force, which increases with the square of the speed. Roads are banked to absorb some of this kinetic energy and change it to friction.

How does air resist motion? One of the most important of the forces retarding motion at high speeds is the resistance of the air. Air resistance increases with the square of the speed. That is, at 100 miles an hour, air resistance is 10,000 times that at one mile an hour.

Two factors determine air resistance. One is the difference in pressure behind and in front of an object. The other is friction.

If an object is so shaped that a partial vacuum forms behind it, air pressure tends to push that object backward. A boxcar is the standard example of such an object. The forward movement increases the air pressure against the front end of the car, and the eddies reduce the pressure at the rear.

To make the air flow more smoothly past a vehicle, it is streamlined. An egg or a falling drop of water has a streamlined shape. The large end of the egg-shaped vehicle is the front. Around such an object, air flows smoothly and meets in a single stream at the rear. Projections set up eddies which increase friction along the sides of the object and create differences of air pressure.

Because of its shape, a fish can keep its head upstream and with very little effort hold its position against a current. The fish is streamlined.

DEMONSTRATION. WHAT FORCES RESIST TRANSPORTATION?

What to use: Wooden darning egg, slender nail, small toy automobile filled with paraffin, coin, card, tumbler, string. weight, support.

What to do: Drive the nail into the darning egg. Hold the egg under the faucet, with the large end up. Turn the water on. Note the smooth flow of water around the egg. Next hold the toy automobile under the stream of water. Observe the uneven flow of water. Try each under a much more rapid stream of water.

Place a coin on a card over the open mouth of the tumbler. With the finger, snap the card off the tumbler.

Make a pendulum by tying a weight to a support with a string. Start it swinging. Observe changes in speed. Change the length of the string, and observe the change in the rate of the pendulum.

What was observed: Describe or draw a diagram of the flow of water around the egg and the toy automobile. Why does the coin fall in the glass? State the effect of length of cord upon the pendulum.

What was learned: In terms of the demonstration, explain the following words: streamlining, inertia, gravity, acceleration.

Exercise. *Make a table by ruling your paper into four columns. Head the columns as follows:* FRICTION, GRAVITY, INERTIA, AIR RESISTANCE. *Below are devices or methods used in transportation to overcome one or more of the above listed resistances. Write these words in the column where they fit best:* smooth surfaces, smooth roads, level roads, egg shape, wheels, pull of propeller, ball bearing, no projections, oil, brakes, straight roads, few stops, lightweight, roller bearings, few grades, polished body surfaces, accelerators.

Science activity. Make a survey of the various kinds of transportation in your community. If the community is large, divide the class into committees, each reporting on one phase of transportation. Arrange to visit railroad terminals, wharves, express depots, airports, and bus stations.

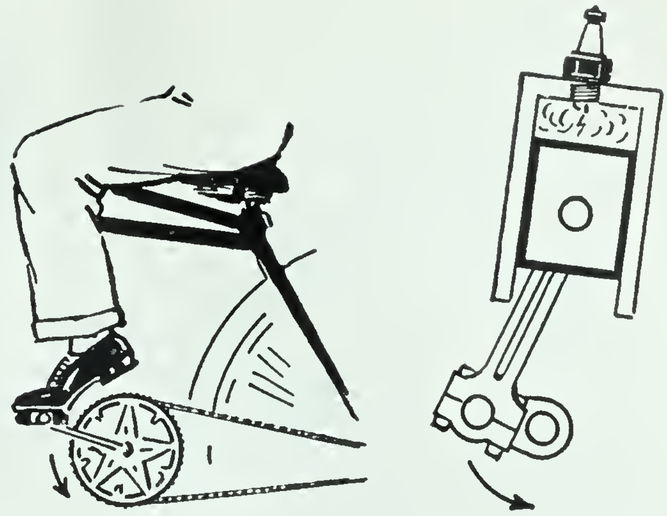
2. How does the automobile use power?

The automobile consists of several parts or systems—the chassis or framework, the body, the power plant, the electrical systems, the transmission system, the cooling and heating system, and other minor parts. Of these the most

essential parts are those which apply energy to turn the wheels.

How does the motor turn the crankshaft? The standard automobile has a four-cycle gasoline engine to provide power.

The force of the exploding gasoline thrusts the piston downward. The piston is really the enlarged end of a lever called the connecting rod. The connecting rod carries the thrust down to the crankshaft. The cranks of a crankshaft operate exactly like the cranks of your bicycle. You ride by causing your feet to exert a downward thrust upon the cranks in turn. The automobile has pistons and connecting rods, instead of feet, and four to twelve cranks on the same rod, instead of only two.

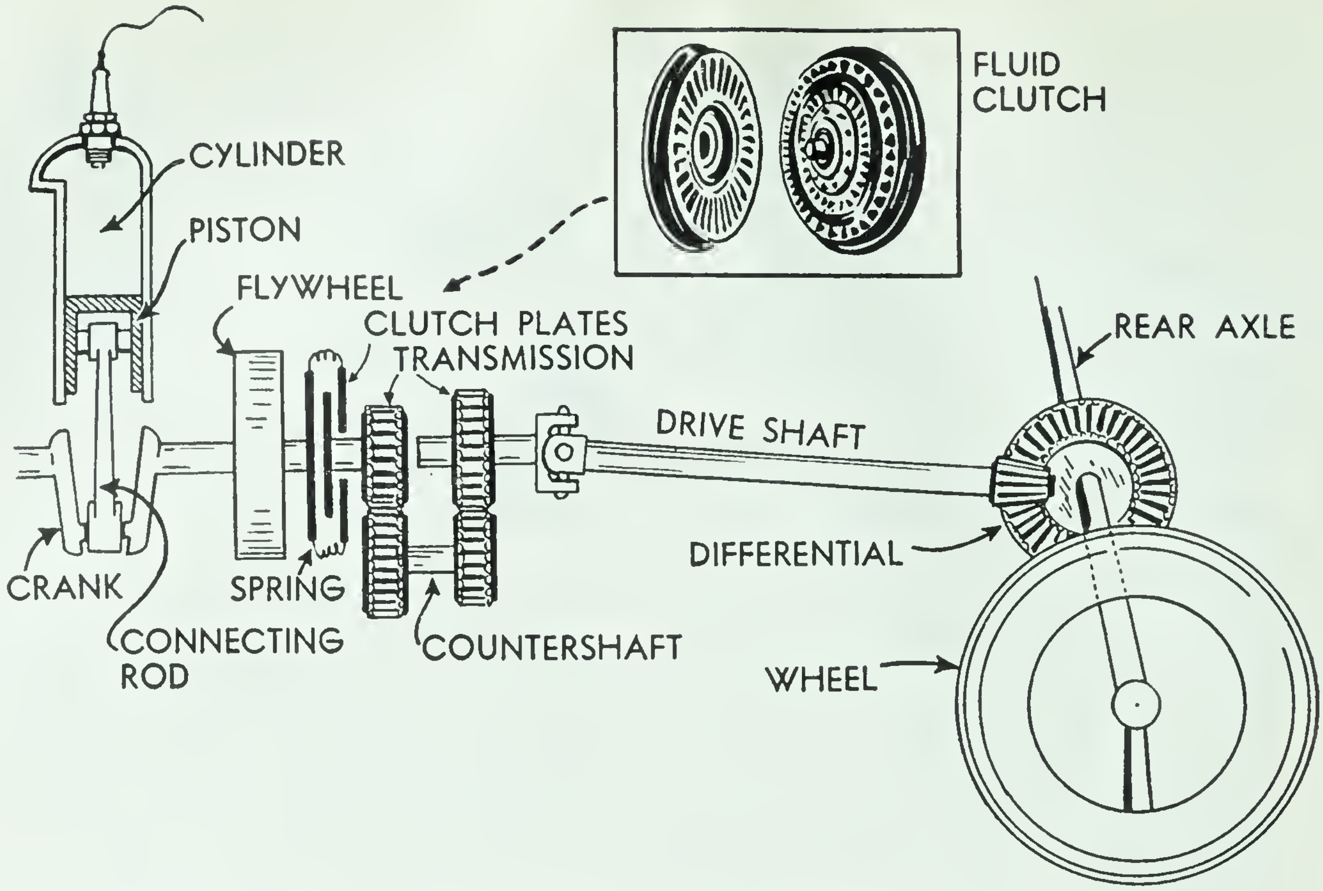


Your foot applies force to a bicycle crank much as the piston connecting rod applies force to the automobile crankshaft. What source of energy in the engine corresponds to your use of food in your muscles?

At the rear of the engine the crankshaft is connected to the flywheel. A shaft connects the flywheel to the clutch.

What is the use of the clutch? It is necessary to disconnect the engine from the load—in this case the automobile—to start it. The starter motor or a hand crank provides energy to move the pistons up and down, pumping fuel into the cylinders in turn and causing the spark to ignite it. Usually several seconds elapse before the correct proportions of air and gasoline are present in the cylinder to cause the engine to start under its own power. When the engine is started, it is necessary to apply the force gradually to overcome the inertia of the automobile. The clutch applies power gradually and permits starting the car smoothly.

The standard clutch is made of three plates. The first and third are connected to the crankshaft. These two are held against the middle plate by springs, and they all turn because of friction. The middle plate is attached to a steel shaft which carries power toward the wheels. When you



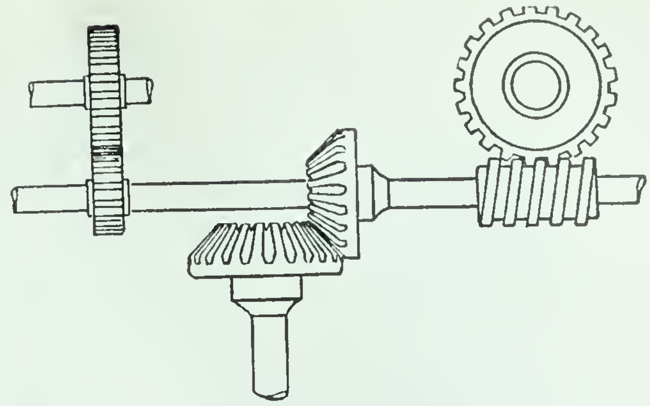
This diagram shows the parts of the automobile which carry force from the cylinder to the rear tire. The standard clutch is shown in the large drawing; the fluid clutch in the inset. The gear shift is in intermediate.

press down on the clutch pedal, you release the pressure of the springs. The plates slip and do not turn the shaft connected to the wheels. When you gradually let the pedal up, the friction increases; and there is less and less slipping, until the force gradually applied moves the automobile smoothly forward. The trick of letting out the clutch pedal is to permit the springs to squeeze the plates together gradually.

The fluid clutch consists of two paddle wheels, both inclosed in a container filled with oil. The first paddle wheel is turned by the engine and causes the oil to whirl. The second is connected to the drive shaft and is turned by the oil whirled around by the first paddle wheel. The oil slips when the engine is turning slowly but applies its force efficiently to the driven paddle wheel when the speed of the engine increases.

What is the transmission? You know that one of the operations of learning to drive most automobiles is the shifting of gears. These gears, taken together, make up the

transmission. The transmission lies just behind the clutch.



There are several types of gears. Three of the most common are shown in this diagram. They are, in order, spur, bevel, and worm gears. These various gears are used to carry power in the automobile.

You know that there are various kinds of gears. The advantage of gears is that they produce changes in direction of force and in mechanical advantage. The mechanical advantage of gears is easily calculated. You count the number of teeth on each gear. If the driven gear has twenty-four teeth and the driving gear has eight teeth, the mechanical advantage of the gears is three—that is, the force is multiplied three times, and the speed is reduced to one-third of what it was. By having the larger gear for the driving gear, the speed is increased, and the mechanical advantage becomes less than one.

The transmission is made up of spur gears. In automobiles the teeth of the gears are curved so that they will slide together easily. There are two shafts in the standard transmission. One shaft goes directly through the transmission and on to the wheels. This shaft may carry power directly from the engine to the wheels when the car is in high gear. This shaft is out-of-gear for low, intermediate, and reverse gears. The second shaft, called a countershaft, is below the first and has a number of gear wheels on it. The gears on this countershaft may be moved back and forth by the shift lever. Various combinations of gears carry the power to the wheels.

When the shift is in low, a small gear is connected to a large gear, increasing the power. The automobile is started in low. To increase the speed, the gears are shifted into second. When shifting gears, the clutch pedal is pushed downward or operated automatically to disconnect the engine from the gears. Automobiles are now so made that part of the work of shifting gears is done automatically.

How is force applied to the ground? The rod which car-

ries force from the gears to the wheels is called a drive shaft. It has in it a joint or hinge which prevents the bouncing of the rear wheels from shaking the transmission apart. The direction of the force must turn at right angles in passing from the drive shaft to the rear axles. To make this turn possible, a bevel gear is used. The driving gear is much smaller than the driven gear. When the automobile is traveling straight ahead, the rear axle turns as a single rod, with the wheels attached at either end.

When the automobile comes to a curve, the outer wheel must turn faster than the inner wheel. The rear axle then separates into two parts. In the middle of the axle is a set of four to six bevel gears, called the differential, so arranged that the power is always carried to the wheel having the smaller amount of resistance to overcome. When the resistance to the wheels is equal, they turn at equal speeds.

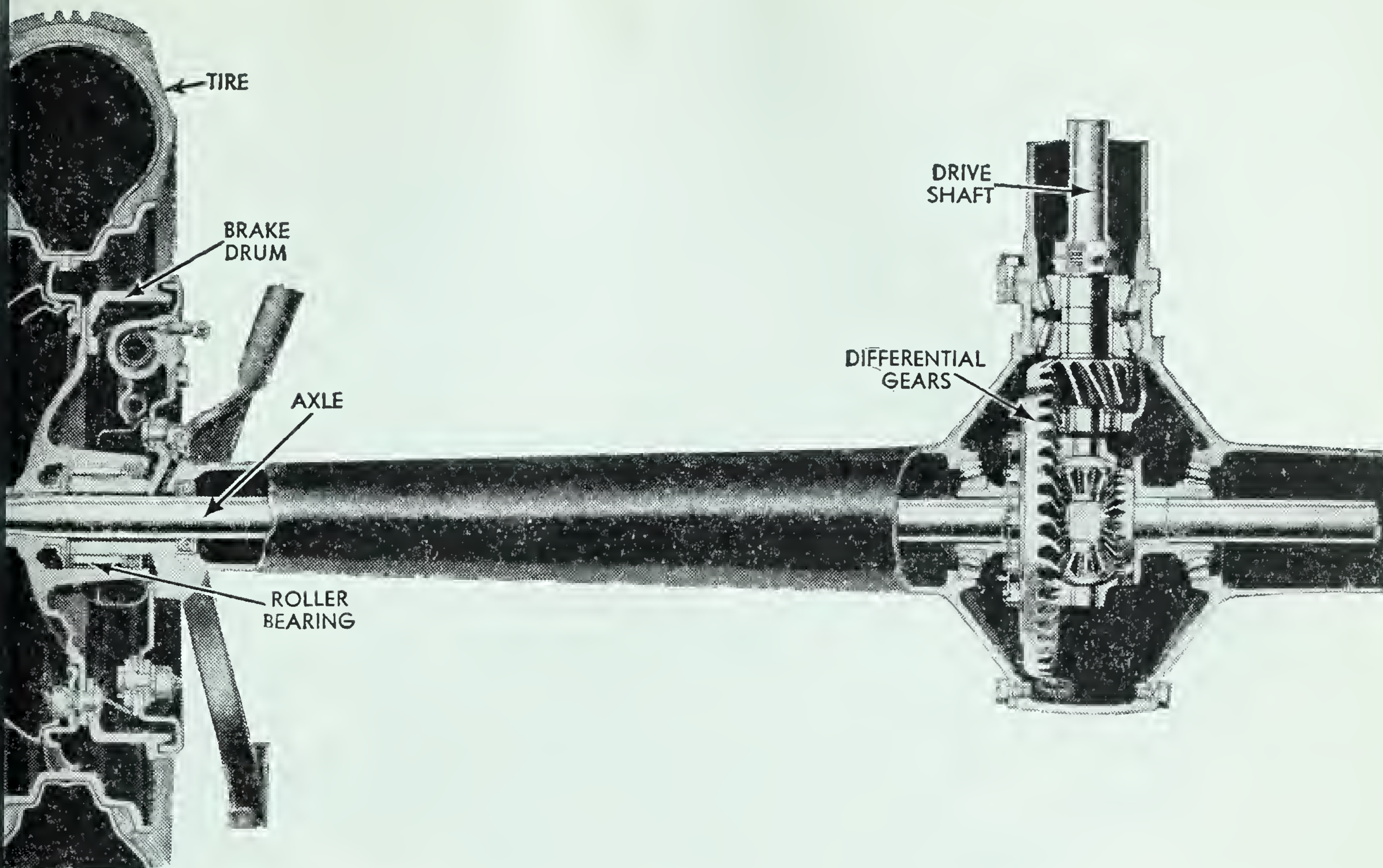
The differential prevents dragging of the wheels and uneven wear on tires, and it makes easy turning possible.

The rear wheels are the final step in carrying power from the engine to the ground. The wheel not only provides rolling friction, but its spokes act as levers which push the automobile along. It is essential that the rear wheels grip the road firmly, or the power is wasted.

What are the other systems driven by the engine? At the front of the engine is a belt passing over three pulleys. The bottom pulley wheel may be attached to the crankshaft, the top pulley to the fan, and the one to the side to the water pump. This pump circulates water from the radiator.

Below and behind the crankshaft pulley is an egg-shaped metal cover. If you remove that, you will see a set of spur gears. These gears may be attached directly or connected with a gear chain. This gear turns a shaft which opens and closes the valves exactly at the right time to admit fuel and to let out the exhaust gases. It also controls the time the spark jumps the gap in the spark plug.

On the flywheel are gear teeth which are engaged by the gears of the starting motor. The starting motor is an ordinary electric motor operated by current from the storage battery. The starter gears are not connected with the flywheel except in starting the automobile.



Courtesy Ford Motor Company

The differential gears transmit power from the drive shaft to the rear wheel.

The generator is used to charge the storage battery and to supply current to the electrical system of the automobile. The generator is frequently placed directly behind the fan in order that the heat produced by current flowing through its coils will be carried away without harm to the wiring. The generator produces direct current. It is connected to an ammeter at the instrument board, where the driver can see whether the battery is being charged or discharged.

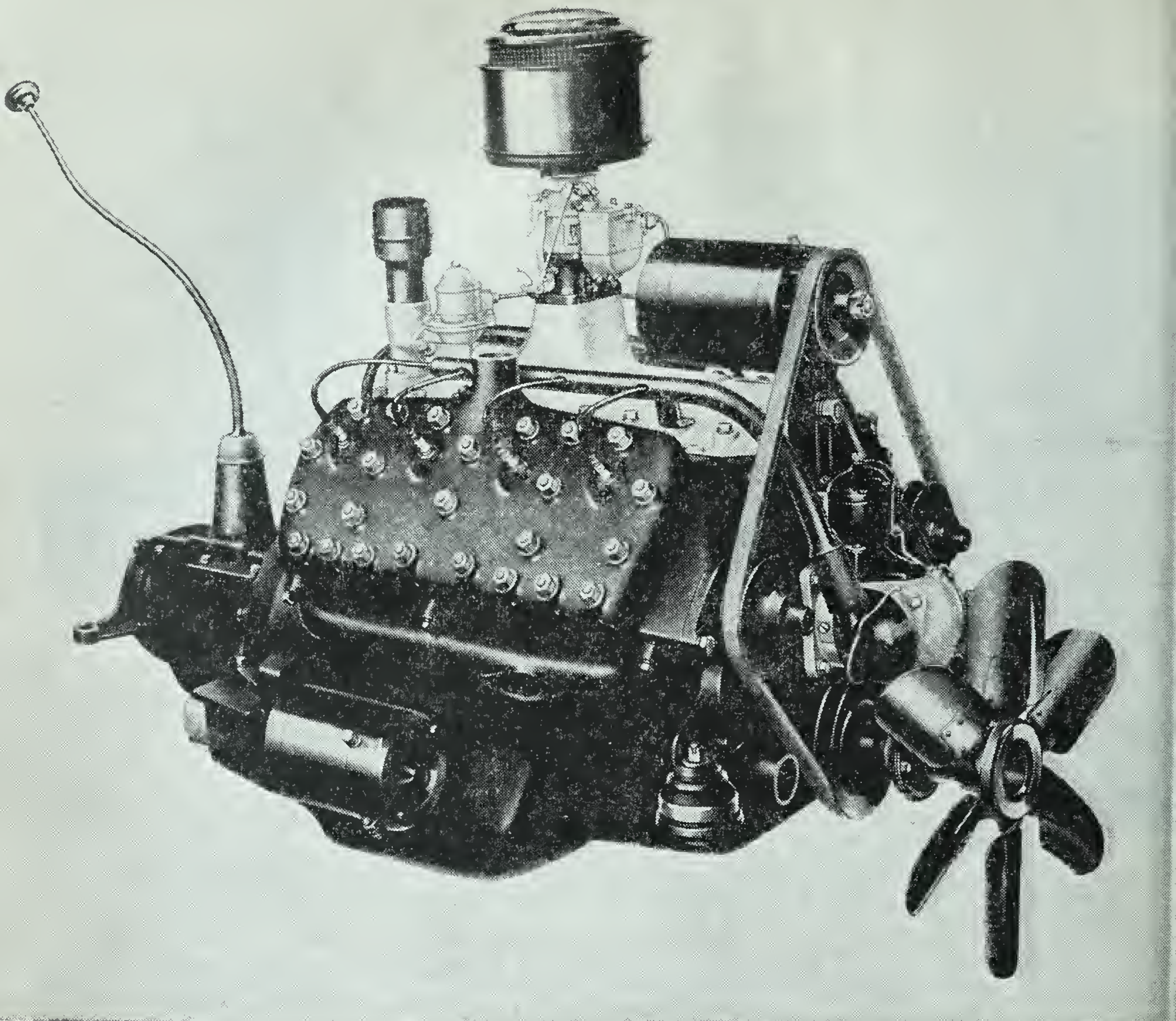
Demonstration. How Do Gears Operate?

What to use: Gears—demonstration, automobile, or clock.

What to do: Count the teeth on the gears. Connect and operate them.

What was observed: Describe the appearance of the gears. How many teeth are on each gear wheel? Which turns faster, the large or small gears?

What was learned: State how the mechanical advantage of gears is calculated.



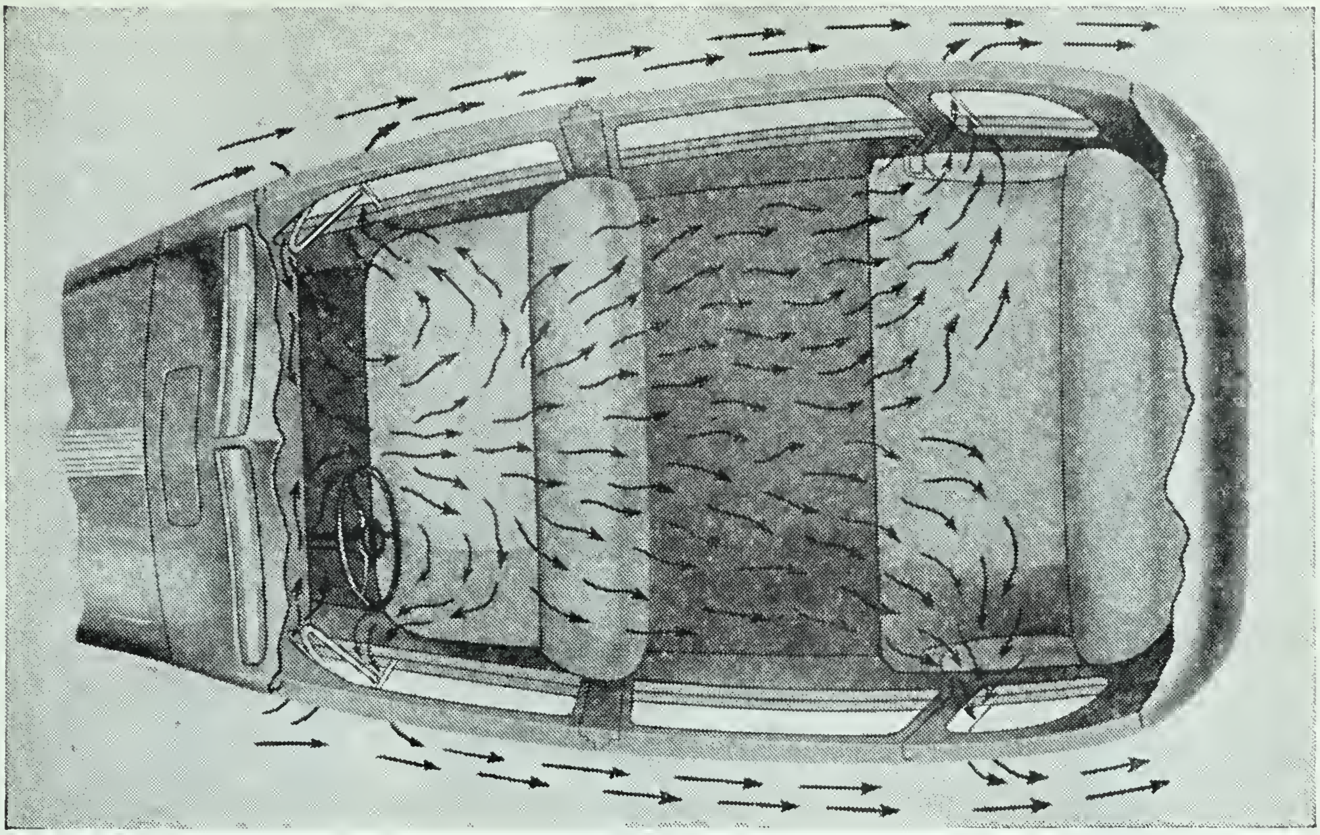
Courtesy Ford Motor Company

This picture shows one of many possible arrangements of pumps, generator, and fan. The fan is mounted on the crankshaft; the belt passes over two pump pulleys and to the generator pulley at the top. How many parts of the engine can you recognize?

Exercise. *Redraw and label the diagram on page 530 showing the relation of the parts of the automobile to each other. Reverse the drawing—that is, have the cylinder on the right. Make your drawing twice the size of the one in the book. Add as many parts to the drawing as you can.*

3. How is the automobile constructed?

The first automobiles were merely horse-drawn buggies with gasoline engines substituted for the horses. Some even had sockets for buggy whips. Almost 50 years of improvement and work have resulted in the automobile of today—



Courtesy General Motors Corp.

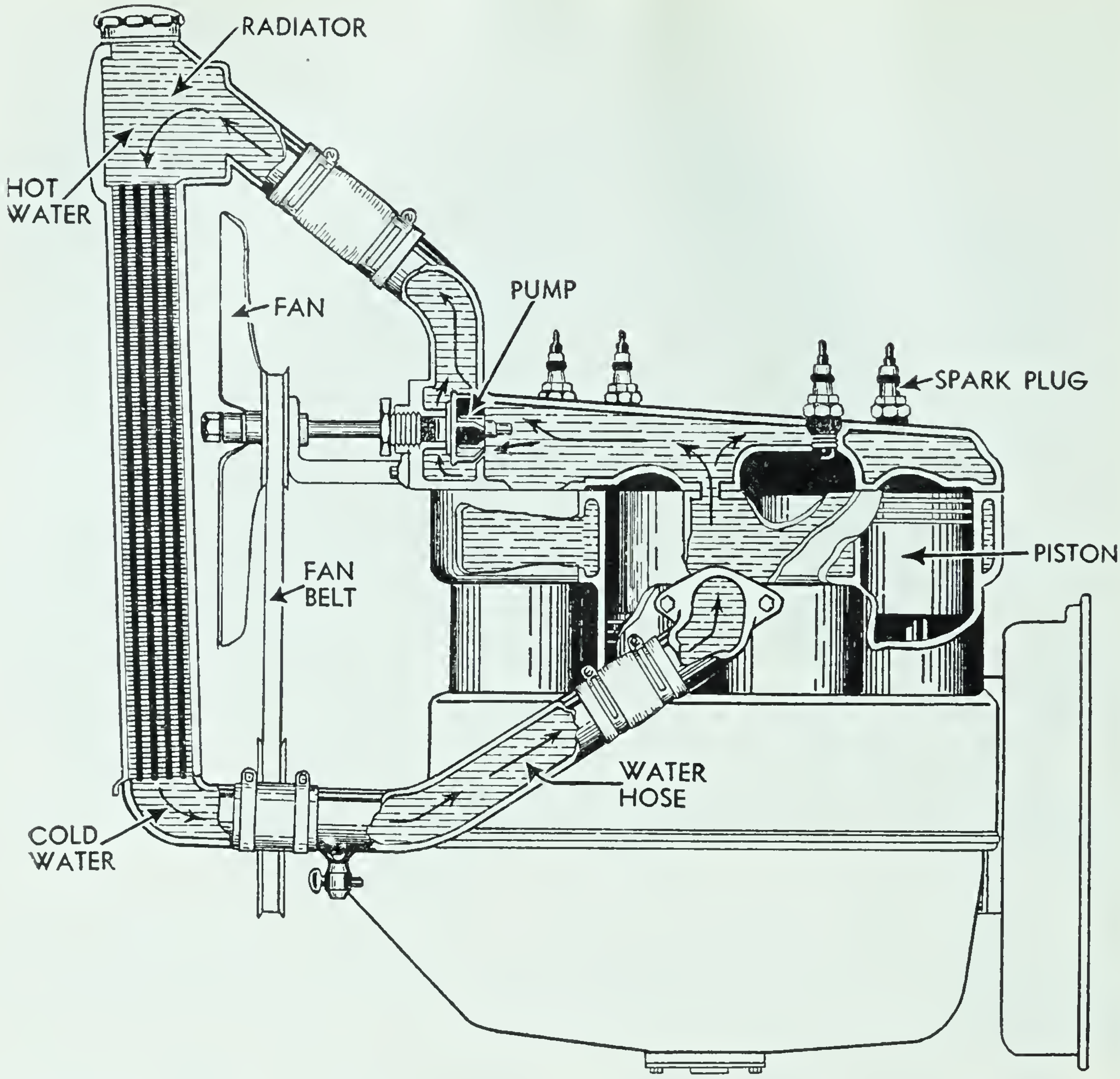
Adequate ventilation is an important safety factor. Small amounts of carbon monoxide cause sleepiness, headaches, and loss of driver's attention.

powerful, fast, and comfortable. Not the least of the improvement of the automobile has been in construction of the body.

How is the body made? Automobiles of today are all built on a modified streamlined plan. That is, surfaces slope at an angle instead of being straight up and down, and corners are rounded. Door handles are sunk into the body, headlamps are molded into the body, and fenders are smoothed and rounded in shape. The automobile frame was once separate from the body, but the tendency today is to make an all-steel body with the frame and body in one piece.

The importance of streamlining is perhaps slightly overestimated. At speeds above 40 miles an hour—that is, in the region of unsafe speeds—air resistance becomes an important factor in economy of operation. Even at 40 miles an hour, more than half the effective energy is used to overcome air resistance. It is probable that the trend toward streamlining will continue.

The ventilation of the automobile is highly important from a safety angle. Carbon monoxide gas frequently leaks into



The cooling system of an automobile is shown here greatly simplified. The principle of the cooling system is one that is easily understood. The natural convection currents are reinforced by the action of the pump. Read the text for further information.

the riding space and causes sleepiness or loss of attention. Many accidents are caused by poor ventilation. Most automobiles of today are ventilated by air from a wing-window combination. Air is directed through the riding zone without causing uncomfortable drafts.

How are the lights constructed? The automobile lighting system is a direct-current, 6-volt system. The lamps use a large number of amperes, compared with house lights, to produce a given wattage, and consequently provide bright light. Automobile lamps are more rugged than house lamps. Reflectors are used to direct the beam to the road. Lamps and reflectors are built as a unit, part of the reflector being

in the bulb itself. They throw the light upon the road and not into the approaching driver's eyes. The use of Polaroid in lights and windshields is being developed to eliminate glare. No automobile has lights good enough to justify driving at night at speeds higher than 35 miles an hour on highways or 25 miles an hour in city traffic.

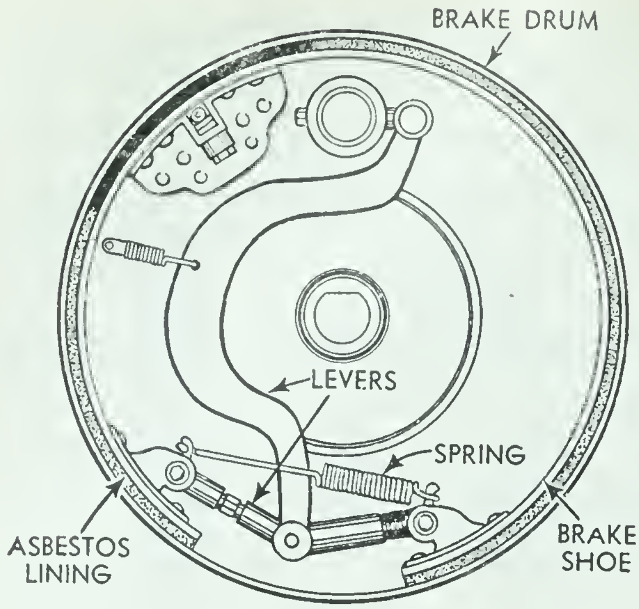
How does the cooling system work? Because the burning temperature of gasoline is high, the engine, if uncooled, would soon become so hot that it would burn the lubricating oil, and the metal would expand until the parts would no longer move. To cool the engine, water is circulated through spaces in the metal block in which the cylinders are bored.

Cold water is stored in the radiator. The radiator and engine are connected by pieces of hose. Water heated by the engine has a natural tendency to circulate by convection. To increase the circulation of water, a centrifugal or rotary pump is driven by a belt from the crankshaft. The water cools in the radiator, falls, passes through the engine and is heated, rises, and is pumped back to the radiator. The fan causes a current of air to cool the radiator. The radiator tubes are connected by metal fins which conduct heat rapidly into the air.

How do the brakes work? There is one brake on each wheel. The brake consists of a metal drum which looks much like a straight-sided saucepan. It is attached to the wheel. Inside the drum is a pair of semicircular bands, called shoes, which barely clear the sides of the drum. When pressure is applied to the brake pedal, these shoes are pressed forcibly against the inside of the drum and produce friction to stop the movement of the wheels.

The shoes are covered with asbestos, interwoven with copper wire, which resists heating, is strong, grips well, and is quite durable. It is occasionally necessary to have this asbestos lining replaced.

Most automobiles have hydraulic brakes. A cylinder or tank of liquid underneath the body is connected to the various brakes. Each wheel brake contains a cylinder and a pair of pistons. When the brake pedal is pressed, a piston force pump forces liquid under pressure from the cylinder or tank to the brake cylinders. The brake pistons press the



This type of automobile brake operates when the shoe inside the drum is pressed outward by the action of the lever arms. The spring keeps the shoe away from the drum when the brake is off.

shoes against the drum. The liquid usually used in hydraulic brakes is a mixture of castor oil and denatured alcohol.

How is gasoline supplied to the engine? A tube runs from the gasoline tank to a force pump which causes the gasoline to run into the tank of the carburetor. In the carburetor the gasoline is mixed with air, and the mixture goes through the intake pipes to the engine. The intake pipe is heated by passing along the engine and past the hot exhaust. The use of heat increases the vaporization of the gasoline.

When a fuel vaporizes slowly, the engine does not have pickup. Low-grade fuel causes a knock. Materials are added to gasoline to decrease the tendency to knock. The measure of knock is called the octane rating—octane being the name of one of several hydrogen and carbon compounds which make up commercial gasoline. A standard mixture of fuel is the basis of comparison with other fuels.

What happens to the energy of gasoline? It is estimated that, under good conditions, only about 7 per cent of the energy of gasoline ever reaches the wheels to propel the automobile forward. The remaining 93 per cent is wasted. The three ways in which energy is wasted are in heating water, in exhaust gases, and in friction, in the order named. Some energy is used for the storage battery and the devices which operate the engine. If a more efficient engine is eventually developed, it must operate at a higher temperature than does the engine used today.

Because it is impossible to heat water above the boiling point — 212 degrees Fahrenheit — and because the rate of movement of heat is in proportion to the differences in temperature, the heat losses with a water-cooled engine cannot be avoided.

The exhaust gases waste energy in two ways. Heat is lost that could be used for power in a more efficient engine. A second exhaust loss is through the escape of unburned gasoline and carbon monoxide. Both these materials contain unused energy. An engine operating at a higher temperature would decrease this loss.

Loss of energy from friction is only slightly less than the losses through water and exhaust heat. Every cylinder, every bearing, every gear, and every moving surface encounters friction. Friction is reduced by use of lubricating oils. The bearings of the crankshaft operate in a bath of oil, and oil is forced by an oil pump through tubes in the engine parts to points where friction is greatest. Grease is used on the bearings of the wheels and in the transmission and differential.

The so-called useful energy—that delivered on the road—is used to overcome road friction, to overcome gravity in going uphill, and in overcoming air resistance. Eventually all this energy is lost.

What does automobile driving cost? A survey of automobile costs in the state of Iowa showed that the average driver drove 7000 miles a year at an average cost of about 6¼ cents per mile, or a total cost of $435 a year. The average daily cost was almost $1.20. Other surveys have shown similar costs. As cost of operation is reduced by increasing efficiency, drivers drive faster and farther, keeping the total cost unchanged.

The automobile may be regarded as the most convenient of all means of transportation, but it is not safe or economical.

Demonstration. What Is the Principle of the Brake?

What to use: Small electric motor, spring clothespin.

What to do: Set up the motor so that it runs strongly and smoothly. Pinch the clothespin to open it wide, and place it around the revolving shaft. Gradually permit the clothespin to close, and note the effect on the motor. Feel the shaft.

What was observed: Can a motor be stopped by use of a brake?

What was learned: What happens to the energy removed by a brake?

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* radiator, fan, belt, pump, friction,

Courtesy U. S. Bureau of Public Roads

Many times it is impossible to make roads both straight and moderate in grade. The hairpin turn shown is unavoidable in hilly country, particularly when costs must be kept low.

exhaust, heating water, power, efficiency, chassis, brake, streamlining, 93 per cent, 7 per cent.

4. How are safe highways constructed?

To make travel safe and economical, it is just as important to have good roads as it is to have good automobiles. The problems of road building are to locate the road correctly, to construct it of durable and suitable materials, to develop the road in relation to the surroundings, to provide for city traffic, and to make certain that the road will be used safely.

How is the location of the road determined? The road must be placed where the people need it most. Farm roads run to near-by towns. Highways connect towns and cities. Superhighways connect one population center with another.

The road must be as straight and level as possible. The U, or hairpin, turn is dangerous, for people often drive off the road because of centrifugal force. Yet no grade should exceed 9 per cent, and few grades should exceed 5 per cent. The grade is measured in the number of feet of rise in 100

feet of distance. By use of cuts and fills, by winding roads around hillsides, and by use of grades, roads are made sufficiently level.

Traffic lanes must be separated to avoid collisions. The three-lane road is one of man's deadliest inventions, for the center lane is the scene of head-on collisions. Modern roads are made with four lanes, with opposing traffic separated by a grassy strip. Cross traffic must also be separated or controlled. The clover-leaf intersection is made with one road passing above the other and with turnoffs provided to prevent left-hand turns.

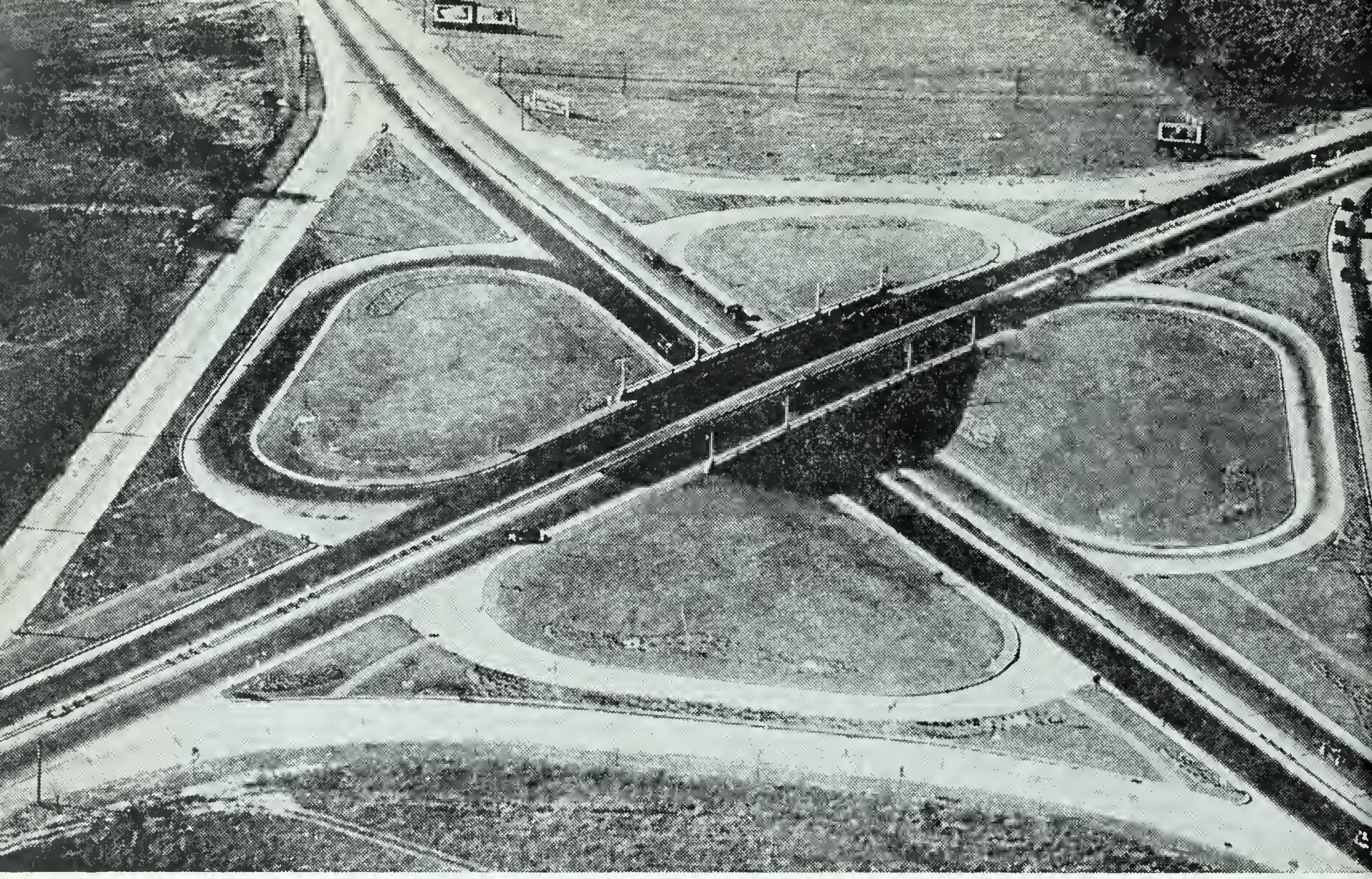
Railroad grade crossings are another danger point. Overpasses or underpasses are the only satisfactory solution for this problem. Grade separation is costly. Part of the cost can be avoided by closing many country roads and city streets which cross railroads.

The road should provide visibility for a distance of 600 feet. Crossroads, side roads, pedestrian crossings, and roadside stands should be visible for this distance. No curve should be blind, unless completely protected by signals.

How are good roads constructed? The first problem of making a road is to provide a solid roadbed. This is done by moving soil and rock from cuts to fills or, in level places, by packing the soil firmly by use of machines. The roadbed is often filled with rock. Ample drainage is a necessity and is provided by use of ditches, tiles, and concrete spillways.

The best roads are made of Portland cement concrete. The next best roads are black top, which is a mixture of gravel or crushed rock with tar or asphalt. Other roads are graded but untreated earth and gravel roads. The half-million miles of roads in the United States are about equally divided among these three types of surfaces.

Concrete is poured on a stone base and usually reinforced with steel bars or with steel netting. Quick-hardening concrete has been developed to speed up road building. Black-top roads may be made by treating gravel with oil, and spreading the mixture on the road, or by pouring the oil on the road and mixing it with the gravel. The mixing is done with scrapers. Heavy rollers then smooth the surface of black-top roads. Untreated roads are made by plowing, scraping, and hauling earth and stone.



Courtesy New Jersey State Highway Commission

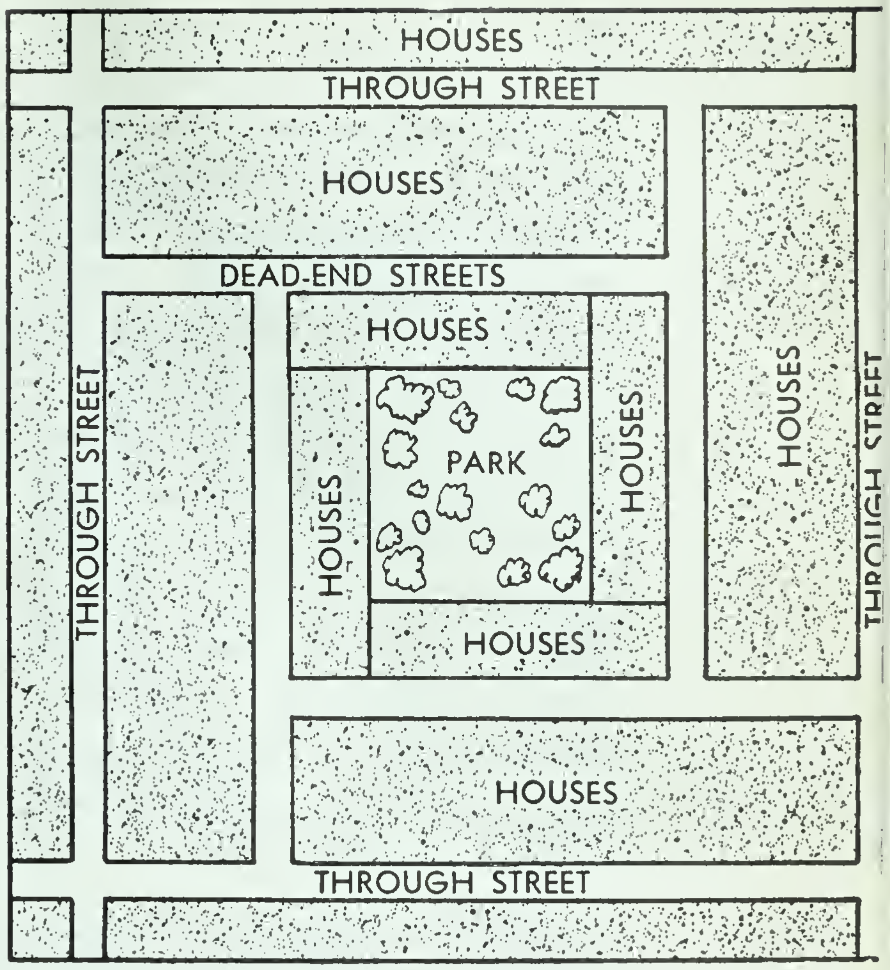
The clover-leaf intersection is the safest crossing so far developed. Its cost makes it practical only where traffic is heavy. Study this picture and tell how automobiles get from one highway to the other without making any left turns.

Concrete roads generally cost more than $35,000 a mile, black-top roads from $20,000 to $30,000, and untreated roads less than $15,000 a mile.

What is good roadside development? The roadside should be developed to aid, not obstruct, the safe movement of traffic. Superhighways are made with clear land, attractively landscaped, for 100 feet or more on each side of the road, gently sloped to prevent a car rolling over if it leaves the road. There are no billboards along such roads nor are there any roadside stands or crossings. The right of way is securely fenced on both sides. Places are provided for turning off to rest or to change tires.

The average roadside is so cluttered with intersecting roads, billboards, stray cattle, pedestrians, farm wagons, filling stations, hamburger stands, and a variety of other means of distracting attention, that it is not amazing that many automobile accidents occur because the driver's attention is distracted from the road.

How should city streets be planned? Most of our cities grew in horse-and-buggy days and still have horse-and-buggy streets. These streets are responsible for many deaths. Streets, for proper use, must be classified to serve definite purposes. Some streets should be declared through-traffic streets and guarded with every possible safety device—overpasses or underpasses, fences, and signals. On these streets there should be no streetcars, filling stations, parking, or cross walks.



This diagram shows the plan of a large city block, one-half mile on each side. It is bounded by through streets. Within the block are dead-end streets and a park playground.

All other streets should be low-speed streets, restricted to speeds of 25 miles an hour or less and controlled by traffic-light signals as needed. In residential districts it is advisable where possible to change street plans to provide for dead-end streets to discourage speeding. Every large block, of the type shown in the diagram, has enough land left over by getting rid of needless streets to provide a park. It is essential to provide playgrounds to remove playing children from the street.

Parking is a problem which no city has solved. The only solution is to provide, when money is available, for off-the-street parking, either inside buildings or on parking lots. Cities are spreading over larger areas because parking is too much of a problem in central districts.

What are the three E's? Traffic engineers say that the three E's are Engineering, Enforcement, and Education. Many traffic accidents may be prevented by building safe roads. Many so-called accidents are not accidents but the

result of willful, criminal disobedience of the law. We must get over the idea that killing a person with an automobile is less serious than killing him with a gun. The only way to curb the criminal driver is to put him in jail when he repeats his offenses. Many so-called good citizens obey all laws but traffic laws.

Education is the need of most drivers. They do not know the danger spots. They are careless in giving and observing signals. More accidents occur at street intersections than at any other point. One-third of the accidents occur between intersections and are caused by running into other cars, pedestrians, or fixed objects. Almost one-fifth of all accidents occur on highways with no reason for the accident except that one or more drivers failed to observe safety rules, either by speeding, driving in the wrong lane, parking on the highway, or driving off the road. Drivers can be educated to improve on this record.

Exercise. *Make a table by ruling your paper into four columns. Head the columns as follows:* RURAL ROADS, HIGHWAYS, SUPER-HIGHWAYS, CITY STREETS. *In the correct column or columns write the following means of increasing traffic safety:* Eliminating roadside stands. Installing or improving traffic lights. Clearing visibility for 600 feet. Eliminating railroad grade crossings. Eliminating billboards. Making roads straight. Using dead-end pattern. Using clover-leaf intersections. Reducing grades to 5 per cent. Permitting no parking. Enforcing strict regulation of speed. Use of footpaths. Eliminating curves.

Science activity. Divide the class into committees to make a traffic survey. Count the number of automobiles passing a given point on various highways at different times of day. Observe and report traffic-law violations by drivers and pedestrians. Locate danger points where accidents are most likely to occur. Report on the use of signs and billboards which take the driver's attention from the road. Check the distance of visibility at intersections and curves. Check placing of signs and signals to discover if they are located where needed. Send a report of your survey to the official in charge of traffic in your city or community.

You can check speed by making two marks on the roadside 176 feet apart. A car traveling 30 miles per hour passes through this distance in 4 seconds. You can calculate other speeds similarly. Use a stop watch. (*Keep off the street!*)

5. Can automobiles be driven safely?

You may wonder—since you will not be old enough to drive an automobile legally for from one to three years, depending upon the laws of your state—why you should concern yourself with driving safely. The answer is this: When you get into the automobile to learn to drive, you will be putting into practice acts that reflect years of thinking and of forming attitudes. If you look upon an automobile as a means of joy-riding, a way of thrilling your friends, and a means of showing off, you should stay out of an automobile as a driver for the rest of your life. If, on the other hand, you know that the automobile is a dangerous, deadly machine, you may be able to learn to drive safely.

Are automobiles really dangerous? Look around you, and select 100 people you know—neighbors, schoolmates, and your own family. Within a year one of them will be injured in an automobile accident in an average group.

In the United States almost 40,000 people are killed every year, and more than 1,200,000 are injured.

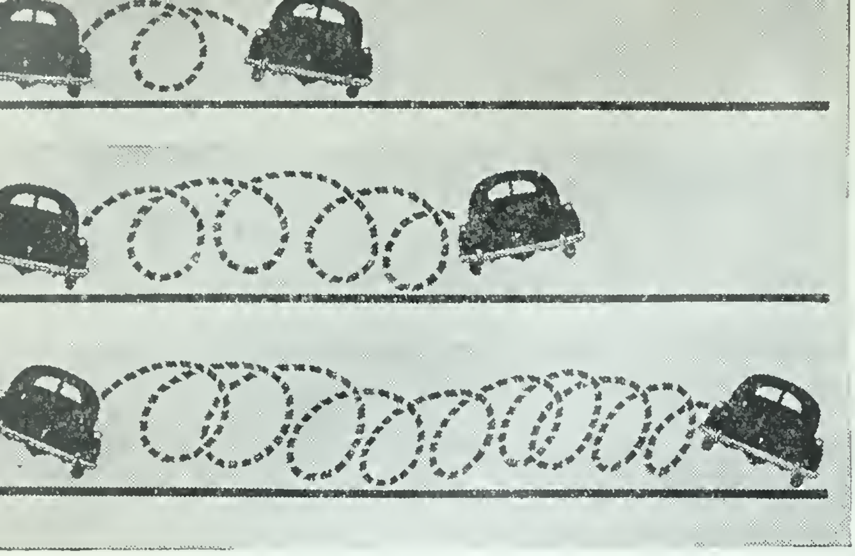
Even if you do not drive, you are not safe; for more than 40 per cent of those killed and 25 per cent of those injured are pedestrians.

Does speed make a difference? Rolling along at 25 miles an hour seems tame. At 50 miles an hour you may still feel that the world moves by slowly. When you are rolling along at 75, you may feel a thrill of pleasure and excitement.

But instead of thinking of rolling *along,* think of rolling *over.*

It takes only a little accident to start an automobile rolling over. At 25 miles an hour, you have about enough energy to roll over once. If your automobile has a steel top, safety glass, and if you are fortunate, you may come out of the accident with minor injuries. At 50 miles an hour, you will roll over, not twice, but *four* times. Accidents of this sort are serious—people are fortunate to come out alive. At 75 miles, you will roll over, not three times, but *nine,* provided the automobile did not strike a tree or other solid object. People rarely survive such accidents.

A collision at 60 miles an hour delivers almost as much



Courtesy The Traveler's Insurance Co.

The force with which you roll over in an automobile accident is in proportion to the square of the speed. The automobiles are traveling 25, 50, and 75 miles an hour. Each loop represents rolling over once.

shock as a fall from a 12-story building. Would you step carelessly from a twelfth-story window?

In going around curves, the same principle holds true. You can make almost any turn you are likely to find in a road at 25 miles an hour. At 50 miles an hour, you can turn only one-fourth as rapidly. And at 75 miles an hour, you can turn only one-ninth as rapidly as at 25 miles an hour. Cutting in, passing, and turning ordinary curves becomes a highly dangerous gamble at high speeds.

This law is a law of physics and will never be repealed. No judge can let the driver off lightly for violating it. No matter who you are or how well you can drive, *the striking force of your automobile increases in proportion to the square of its speed.*

What are the worst driving conditions? Have you ever wondered how you could get into the most dangerous possible driving situation—the one that would be most likely to result in a serious accident? There are probabilities that are almost certain to cause an accident, if we get enough of them together.

If you are hunting for an accident, go out with a young driver—one who has driven for several years and is skillful and overconfident. Find a driver who has had an accident or two. If you want to be most seriously hurt, sit in the front seat beside the driver. Study of many accidents shows that this is the most dangerous seat in the automobile.

Select a clear, dry summer day which encourages speeding. Then go out on Saturday or Sunday evening between seven and eight o'clock. This is the most dangerous time of the day and week. People are reckless, the roads are crowded, and at dusk the driver can see only a short distance ahead.

Then, if you do not have a serious accident, have the

driver become intoxicated. If you are still alive, obtain an old, rattletrap car, crowd four or five people into the front seat, and speed along shouting and paying no attention to the driving.

You may think only a crazy person would deliberately go out to have an accident. True enough. But how many crazy people do you know—people who drive under exactly the conditions described above for an accident hunter? Do they think they are crazy or merely clever?

Courtesy The Traveler's Insurance Co.

The shock of hitting a solid obstacle at 20 miles an hour is the same as the shock of falling from a one-story building. At 40 miles per hour, the shock equals that of a four-story fall; and at 60 miles per hour it equals that of a fall from a 12-story building.

Can people drive at high speeds with safety? There is one part of the driving mechanism of the automobile that can't be made safe—the driver. The old 1915 model driver will sit at the wheel of the 1960 model automobile.

The human nervous system reacts slowly. It takes about half a second to see a situation and to act in any way. Even if the driver is fully alert, he cannot normally put the brakes on in this short a time. In half a second, at 40 miles an hour, the automobile travels 29 feet. For this distance the automobile is absolutely out of control—driverless as far as any power to act is concerned.

When the driver finally reacts, the distance the car travels before it is stopped depends upon the square of the speed. Even at 40 miles an hour, more than 100 feet are required for the brakes to stop an automobile under favorable conditions. At 55 miles an hour, more than 150 feet are required.

What rules should you observe when you learn to drive? On the next page are nine rules for drivers to observe.

1. Drive more slowly than you think is the safe speed. *Be sure* that you can stop within the distance that you can see ahead.

2. Stay on your own side of the road. No matter how safe the road seems, keep well to the right. Never pass the center line or even approach it closely on hills and curves.

3. Wait to cross until you have the right of way.

4. Don't cut in and out of traffic. Get in your lane and stay there.

5. Stop behind standing streetcars, and go carefully around parked automobiles.

6. Use the signals legal in your community. The other fellow is not a mind reader.

7. Drive so cautiously that even in case of a blowout or other accident you could stay on the road. Never show off. Keep your mind on driving.

8. Do not go on the road until you can perform every operation of driving an automobile five times in succession without an error, with a competent teacher checking your driving. This includes stopping at signals, giving signals, turning, parking, shifting gears, starting quickly, and all other operations necessary to go through traffic. Practice where there is no danger—on a roped-off street, a vacant lot, or an open field.

9. Do not drive for more than three hours without resting. Do not drive more than five hours in one day. Fatigue is a major cause of fatal accidents.

Demonstration. What Is Your Reaction Time?

What to use: Coin, ruler.

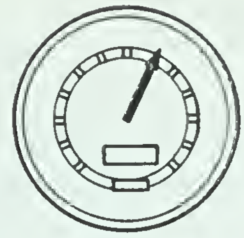
What to do: Stand about two feet away from your subject, who should stand with his feet together facing you. Hold the coin loosely between your thumb and forefinger 30 inches above the floor. Have the subject watch the coin. Then, without warning, drop it, and let him try to thrust his right foot under the coin. Try this five times.

If the subject fails three times in five, drop the coin from a height of 48 inches, and repeat. If he still fails, drop the coin from a height of 70 inches. A coin falls 30 inches in 2/5 of a second, 48 inches in 1/2 second, and 70 inches in 3/5 of a second.

What was observed: Work this problem: With your own reaction time, through what distance would you be out of control driving a car at a speed of 45 miles an hour. At this speed, an automobile travels 66 feet a second.

What was learned: What is a safe driving speed?

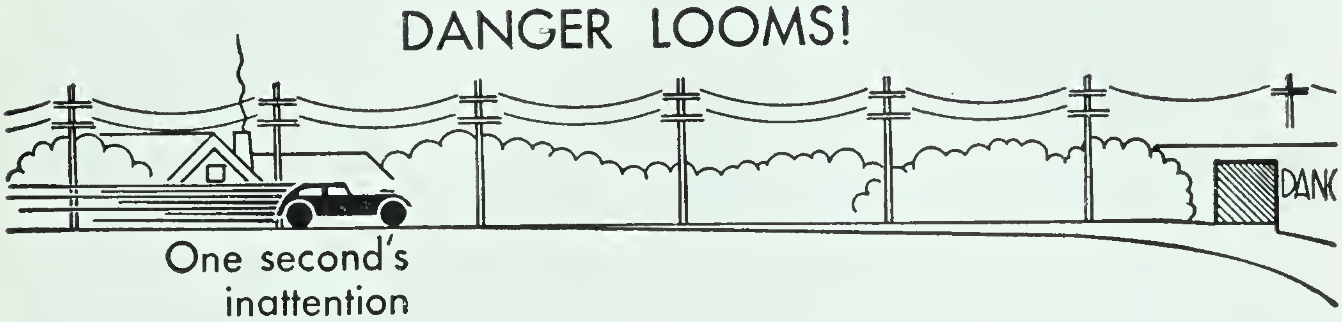
"YOU BET YOUR LIFE"



WHEN YOU DRIVE AT HIGH SPEEDS

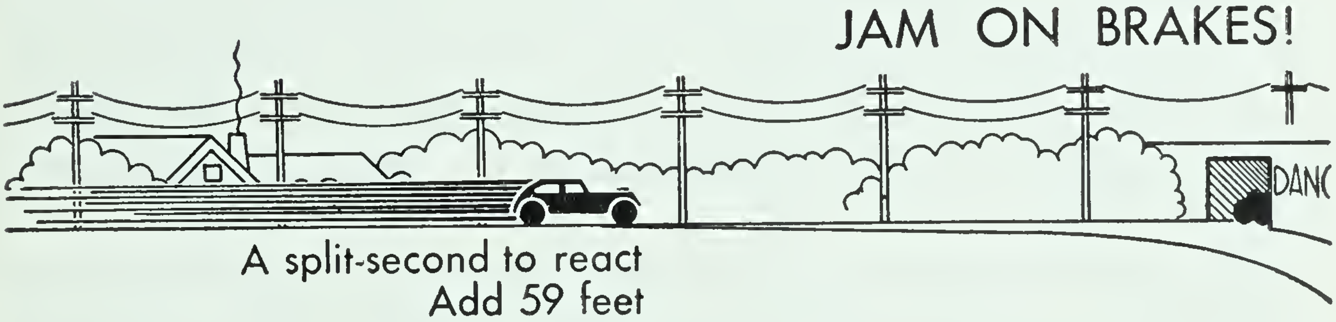
For instance
--------------at 55

DANGER LOOMS!



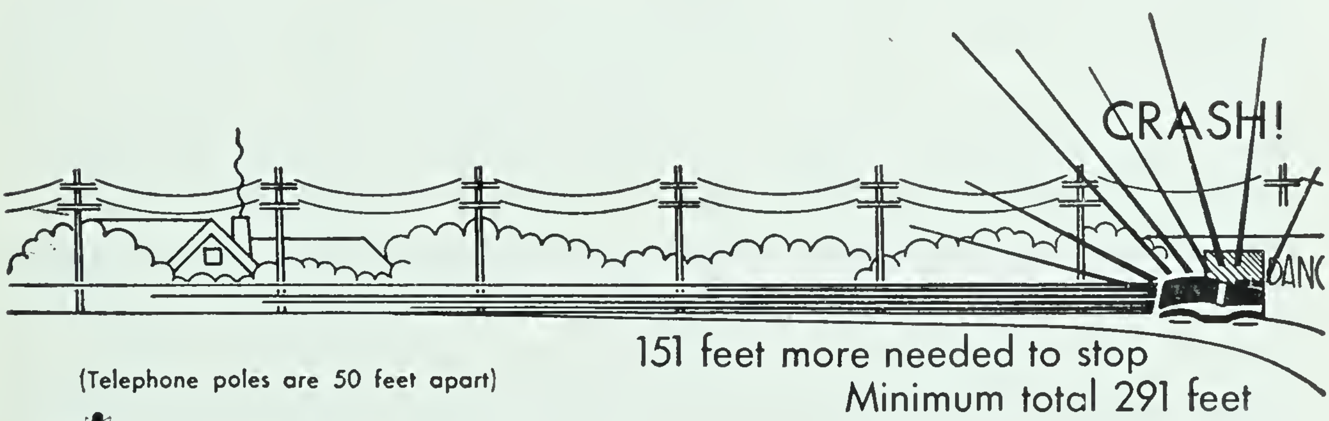
One second's
inattention
You travel 81 feet

JAM ON BRAKES!



A split-second to react
Add 59 feet

CRASH!



151 feet more needed to stop
Minimum total 291 feet

(Telephone poles are 50 feet apart)

PICTORIAL STATISTICS, INC.

Few automobile drivers realize that, no matter how well they drive, their automobiles are actually out of control for more than half a block at ordinary driving speeds. Besides being safer, low speeds conserve tires, gasoline and oil, and make the automobile last longer.

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* square of the speed, force, collision, one-third of a second, after dark, 40 miles an hour, reaction time, safest speed, 40,000, pass on curves and hills, signal, right of way, front seat.

6. Why do aircraft fly?

The airplane is today one of the essential factors in national defense and in transportation. While the total number of passengers carried and the total number of tons of freight hauled is not great compared to the volumes carried by trucks, automobiles, and trains, it still is considerable.

Airplanes and balloons have certain problems to solve that are of little significance to other transportation devices. Two of these deal with overcoming air resistance and gravity.

What is lift? If an object is to remain suspended above the earth, it is plain that a lift must be exerted in proportion to the weight of the object. The two ways of obtaining lift in practical use are by use of gases lighter than air in balloons and by use of differences in air pressure upon airplane wings.

Why do balloons rise? The smaller balloons are nonrigid. They consist of a bag to hold the gas and a harness attached to the bag to support the carriage or car. The envelope consists of a sack made of silk cloth, lined with the intestines of cattle or of cloth treated with rubber. The cloth is treated or "doped" with a solution of the material of which some photographic film is made (cellulose acetate). No matter what type of bag is used, some of the gas escapes through the bag, and eventually more must be supplied. The process by which the gas escapes is called *diffusion* and is the result of the activity of the molecules of the gas as they strike the bag.

The Zeppelin type of dirigible [dĭr′ĭ·jĭ·b'l] balloon has a frame of metal hoops connected by girders, or metal bars, running lengthwise of the ship. The car is suspended below the framework. Gas bags fill the spaces within.

The lift of balloons comes from use of hydrogen or helium. One thousand cubic feet of hydrogen gives an average lift of about 68 pounds. Helium gives a lift of about 63 pounds per 1000 cubic feet. A dirigible 810 feet long and 100 feet in diameter has a lift of about 125 tons. Helium is completely inert and will not burn or explode. Hydrogen is highly explosive and has been responsible for the explosions which have wrecked some of the largest dirigibles.

Courtesy Goodyear Tire and Rubber Co.

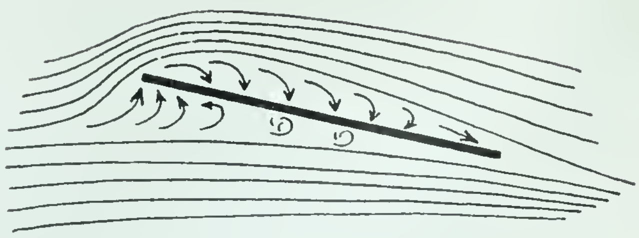
The lift of balloons is provided by a light gas. The gas displaces the heavier air, and the balloon tends to rise just as a block of wood tends to rise when placed under water.

As a balloon rises, the tendency of the gas in the bag is to expand as the air pressure decreases. In a rise of 1000 feet, the gas expands about one-thirtieth in volume. The lift is controlled by permitting gas to escape from the bags and also by throwing ballast from the balloon.

Balloons are of less commercial importance than are airplanes. They are used for commerce, for weather observation, and for military purposes.

What causes the lift of wings? While the lift of a balloon is constant, whether the balloon moves or not, the lift of airplane wings is dependent upon their forward motion through the air.

A kite remains in the air when it is held at the proper angle in a strong wind. The air flowing on the lower side of the kite exerts a greater force than does the air flowing along the upper surface. Because of the inertia of the moving air, the air which is deflected (turned aside) upward by the leading edge of the kite does not immediately return to a position close to the upper surface. There is, as a result, an



Flow of air around a kite is uneven and shows evidence of many eddies. Although a kite remains in the air because of pressure upon its lower side, its flight is jerky and unsteady.

area of reduced air pressure along the upper surface of the kite, and the kite tends to rise against gravity. The kite flies unsteadily because of eddies of air around it.

To overcome the tendency of the air to form eddies, the shape of the airplane wing is planned to cause the air to flow from it smoothly in a streamline fashion. The leading edge is rounded, with the more convex curve on the upper side. The leading edge is thicker than the trailing edge. The lower surface of the wing is either slightly curved or straight, depending upon the speed for which the plane is designed.

As the wing is moved forward into the air, the amount of lift increases with the square of the speed.

The wings are tilted with the leading edge higher than the trailing edge. If the angle is too great, eddies form along the upper surface. If the angle is too small, the eddies form on the lower side of the wing. Eddies upset the balance between the pressure beneath the partial vacuum above the wing.

What produces forward motion? Just as the ability of aircraft to remain in the air depends upon a balance between gravity and lift, so does its forward movement depend upon other opposed forces. The forward force of the propeller is called *thrust;* the backward force of the air upon the parts of the plane is called *drag.*

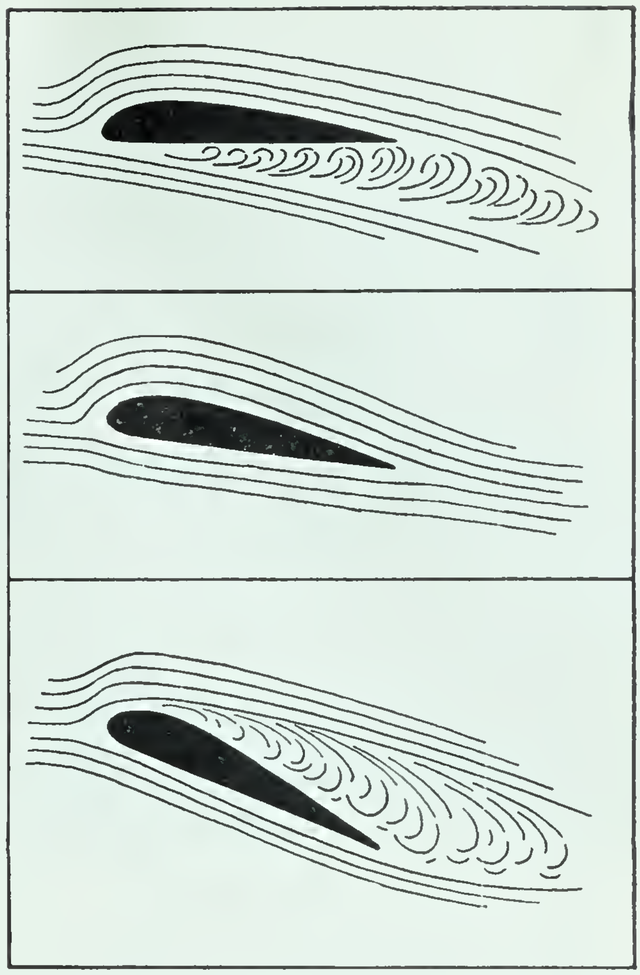
The propeller may be thought of as a section of a screw, so made that its pitch pushes it through the air just as a wood bit bores through wood. The thrust of a propeller depends upon its velocity, its length, its pitch, and upon the number of revolutions it makes per minute.

To understand the reason a propeller has thrust, you must consider it to be the same as a wing in its action—that is, there is a region of decreased air pressure in front of the propeller and a region of increased pressure behind it. The

rounded side of the propeller is in front, the flat side to the rear.

Drag is the result of eddies caused by the inertia of the air and of the friction of the plane moving rapidly through the air.

If you hold a square cardboard, with its flat side toward the air flow, at arm's length from a window of a slowly moving automobile, you will find that the air offers only slight resistance to the card. If, however, the speed is increased, it soon becomes impossible to hold the cardboard in the position described. Since the resistance of the air increases with the square of the speed, increasing the speed five times increases the air resistance 25 times.

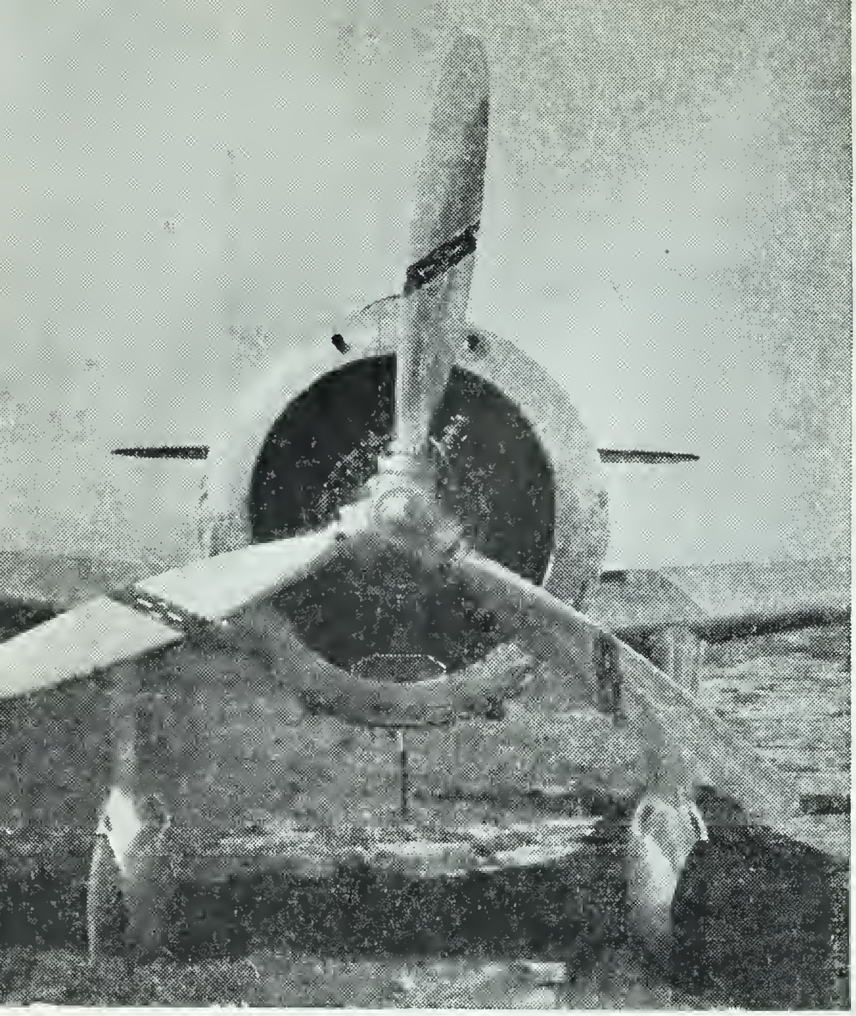


The black figure represents the cross section of an airplane wing. When moving forward at the correct angle (*center*), the flow of air around the wing is smooth. When the wing is tilted at too small an angle (*top*) or too large an angle (*bottom*), eddies are set up and the even pressure beneath the wing is disturbed.

Because airplanes rarely fly at speeds of less than 100 miles an hour and often fly at speeds of 200 to 300 miles per hour, the problem of wind resistance is of utmost importance. A small rod which is shaped to resist wind has the same power to retard movement at high speeds that a small sail would have at low speeds. At present speeds of transportation, the only real problem of streamlining exists in relation to airplanes.

There are two types of drag. The wing drag is in proportion to the weight of the plane and its load and to the area of the wing. Wing drag is necessary, for it is the force that makes possible lifting of the plane.

Parasite drag is caused by air resistance to parts of the plane other than the wings and does no good at all. Parasite



Courtesy Curtiss-Wright Corp.

This three-blade propeller provides the thrust necessary to overcome the drag of the plane. The propeller is turned by a radial engine. Visible at the rear of the plane are the tips of the elevator.

drag is caused by struts, the wires which control the steering surfaces, the heads of rivets which hold the plane together, the uneven surfaces caused by instruments and windows, and other projections. Because uneven shape causes eddies of air which exert pressure upon the parts of the ship, modern airplanes have the braces, struts, wires, and controlling mechanism, including the landing gear, carried inside the plane when it is in flight.

Demonstration. How Does Air Lift a Curved Surface?

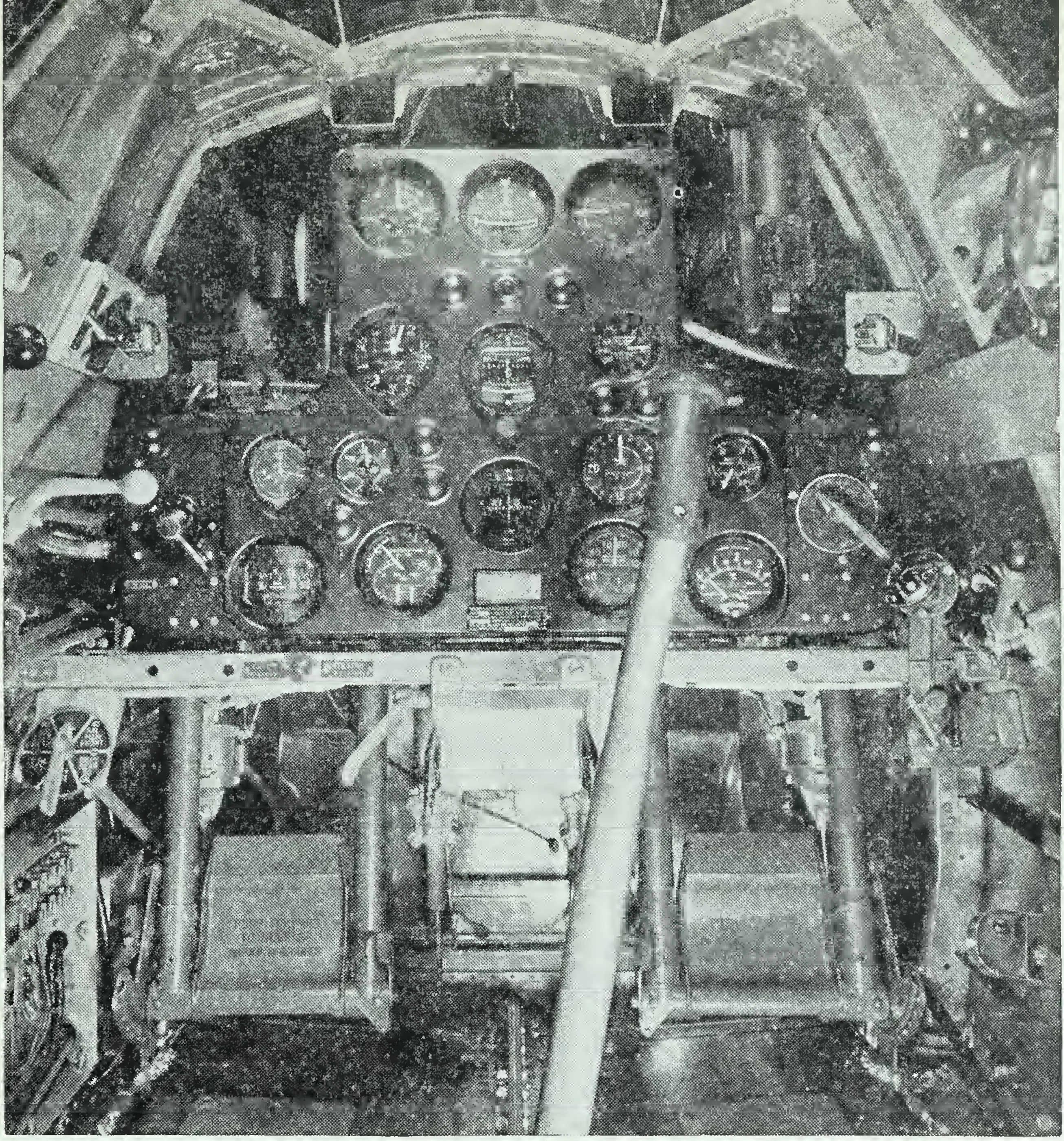
What to use: Book, sheet of paper.

What to do: Crease the paper in the middle, crosswise. Fold it. Curve one-half of the paper to make it convex. Put the flat half inside the cover of a book. Blow on the folded edge of the paper.

What was observed: Describe the movement of the paper.

What was learned: Why did the sheet of paper rise?

Exercise. *Complete the following sentences:* Lift is provided to aircraft by using —1— which is lighter than air or by creating differences in —2— upon wing surfaces. Gas escapes from balloons by —3—. The lift of hydrogen is about —4— pounds per 1000 cubic feet. The —5— surface of a wing is convex, the —6— surface nearly flat. Because air has —7—, it flows unevenly above the upper wing surface, creating a —8—. —9— lifts the plane. The propeller is a —10— which turns through the air, causing a force called —11—. The resistance to movement is called —12— and is caused by resistance of the —13—. The resistance to movement increases with the —14— of the speed.



Courtesy Curtiss-Wright Corp.

This comparatively simple instrument board of an airplane shows air-speed meter, bank indicator, and vertical-speed meter at the top. Other instruments indicate altitude, direction of turn, temperature, and operation of the engine.

7. How are airplanes constructed and operated?

The airplane is made of many and complex parts. Of these, the main parts are the power plant, consisting of the engines and propellers, the lifting surfaces or wings, the body of the airplane, and the controls. Then also, there are the many instruments which assist the pilot in guiding and flying the plane.

What is the airplane power plant? The four-cycle gasoline engine is the standard airplane power plant. The engine used is similar in most respects to that used in automobiles,

except that it is made lighter in proportion to the total power it produces.

Because of the low pressure of the atmosphere at high altitudes, it is necessary to use a supercharger to provide a sufficient supply of oxygen to the engine. The supercharger is a fan or blower operated at high speeds, making from 12,000 to 30,000 revolutions per minute, and is operated by an exhaust-driven turbine or by a separate engine.

For high-altitude flying a radiator and water-cooling system are often used to cool the engine, adding to its weight but increasing its efficiency. Instead of using water in the radiators, another liquid of the alcohol type may be used. Its high boiling point makes it superior to water and permits the radiator to be decreased in size by three-fourths. For low-altitude flying and for smaller planes, the air-cooled engine is superior. Air-cooled engines are of the radial type.

In the radial type of engine the cylinders are arranged like the spokes of a wheel. The number of cylinders may range from 5 to 10, each separate from the rest except where they join in the center at the crankcase. The cylinders may also be arranged in a line, like the standard automobile engine, or in two lines, like the V-type engine. Other arrangements are in three lines, called the W-type, and in four lines, called the X-type.

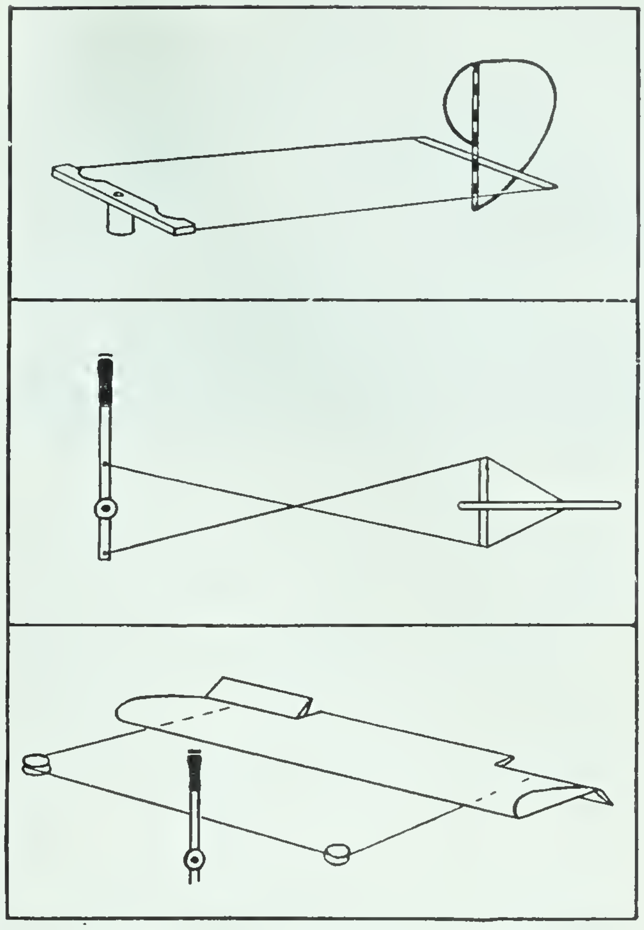
The propeller has already been discussed. It should be noted that the pitch of a propeller—the angle at which it varies from the plane of the circle through which it turns—is steeper near the hub and lower at the tips.

How are the wings built? There are two types of planes in use: the biplane and the monoplane. The two-winged biplane offers greater lift than the monoplane but has more outside braces, and each wing sets up air currents which interfere to some extent with the operation of the other plane. The biplane is somewhat stronger in construction than the monoplane. The monoplane wing is now braced inside, or internally trussed, to reduce the parasite drag, making possible greater efficiency and speed. The monoplane gives greater visibility than does the biplane. The biplane today is much less commonly used for large air-

planes than is the monoplane. The older triplane has disappeared from practical use.

When two wings are used, the upper wing is placed considerably in front of the lower wing.

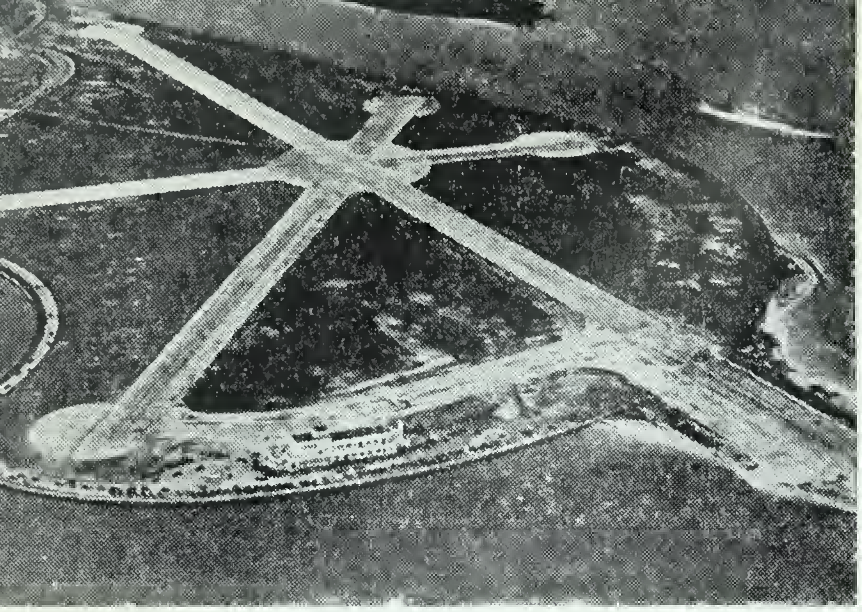
How are the airplane body and landing gear built? The fuselage [fū′zĕ·lĭj], which contains the power plant, the cabin, and cargo space, is the body of the airplane. To it are attached the wings, tail, and landing gear. Almost perfect streamlining of the body is necessary to reduce drag.



This diagram shows the controls of an airplane in their simplest form. The rudder (*top*) controls movement to left or right. The elevator (*center*) controls movement up and down. The ailerons (*bottom*) are used in turning and to keep the wings level.

The type of landing gear depends upon the use to which the airplane is put. The wheel type is commonest for land planes, with the wheels arranged like those of a tricycle. For flying boats, either boat or float type of landing gear is used. Skids and ski-type gear are also sometimes used. Combinations of kinds of landing gear are used; for example, an amphibian may have both floats and wheels, enabling it to land on either land or water. For high-speed flying and for long-distance flights, landing gear is usually pulled up into the fuselage of the plane by levers to reduce parasite drag. The goal of aircraft design is to produce a perfectly streamlined fuselage.

How do the controls work? There are three controls used with the airplane: the rudder, the elevator, and the ailerons [ā′lĕr·ŏn]. The rudder controls flight in a course either straight ahead, left, or right. It acts upon the air in the same manner that a rudder of a boat acts upon water—that is, it serves as an inclined plane upon which the air pushes. The elevator acts as a rudder but in a direction



Courtesy Civil Aeronautics Authority

The safety of flying depends to a large extent upon adequate provisions for landing. This airport at Tampa, Florida, has ample runways for taking off and landing, and has other equipment necessary for safe flying.

parallel to the ground. The ailerons are hinged flaps, attached to the rear of the wings, used either to keep the wings level or to cause the airplane to roll by turning one wing up and the other down.

The rudder usually is operated by a foot bar or pedals, the two being connected by wires. The steering bar operates in a manner somewhat the same as that of a sled. The elevator is operated by the stick, which is pushed forward to bring the nose of the plane down. To bring the nose of the plane up, the stick is pulled back, raising the elevator. The ailerons are controlled by a stick or wheel.

What instruments are used in flying? While the number and complexity of flying instruments is so great that we cannot hope to explain them fully, it is worth while knowing how flying is safeguarded.

Two devices serve to explain how altitude is measured. The aneroid-type altimeter is an aneroid barometer with a scale reading in altitude above sea level. It operates upon the well-known principle that air pressure is reduced as elevation increases. This type of altimeter has two serious flaws: It varies with changes in weather and gives elevation above sea level instead of above the ground.

The second type of altimeter is called the radio-echo altimeter. A tiny radio sending station is located on the wing tip. Short radio waves are sent to the ground and reflected back. A receiving set receives both the sent wave and the echoed wave. The greater the distance to the ground, the more the waves are out of step. The altitude is measured by a dial. This altimeter has been proved in experimental use to be delicate enough to indicate when an airplane flies over a bridge across a valley. This altimeter has done much to eliminate the disastrous crashes into mountains that occurred before its invention.

Other instruments measure the rate of climbing and of losing altitude. There are various devices used for determining the speed of the airplane in relation to the air and to the ground. As you know, an airplane traveling 100 miles an hour with the wind is actually going faster than is an airplane traveling 100 miles an hour against the wind.

There are also various types of compasses in use. One type is a magnetic compass. Another is made up of small coils which are rotated to cut the earth's magnetic field.

Another compass contains a gyroscope [jī′rȯ·skōp]—a top-like wheel which spins with sufficient inertia to keep it from being turned rapidly. Since the gyroscope resists being turned, it is a valuable device in measuring the rate of turning.

Other instruments indicate whether or not the plane is level, how far the nose is above or below the tail, and whether the plane is banking or not. Instruments also inform the pilot of the number of revolutions per minute made by the propeller, of the pressure of the oil, of the amount of gasoline, of the flow of fuel, of the engine temperature, and the current produced by the generators.

Finally, there is the radio equipment. Transport planes are so equipped that they can follow radio beams which direct them on their courses and to the landing fields. This equipment is quite complex in its operation, but with it pilots frequently land planes without being able to see anything but their instrument boards. Devices are in use which take the landing of the plane from the hands of the pilot and permit its complete control by radio from the ground. Such control sometimes increases safety of landing.

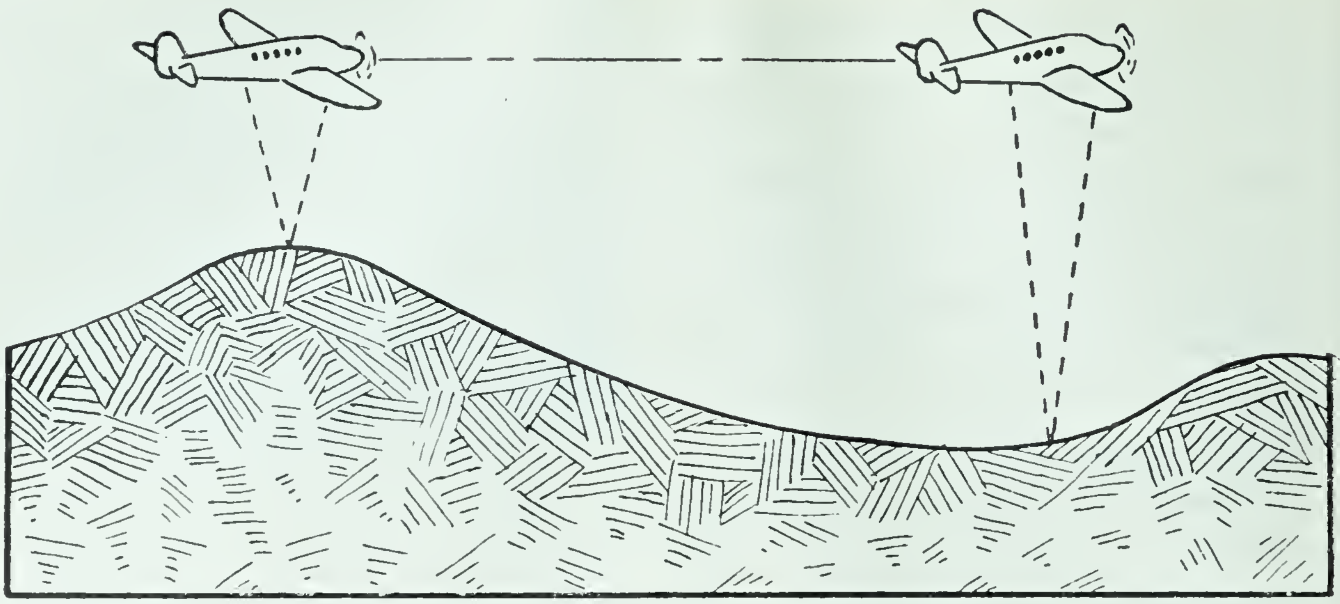
Demonstration. What Is a Gyroscope?

What to use: Small gyroscope, string, stand.

What to do: Spin the gyroscope by winding a string around the shaft and pulling it sharply. Stand the spinning gyroscope upon its stand. Balance it upon the string held tightly in the hands like a clothesline. Hold the gyroscope in the hand, and turn it quickly.

What was observed: Describe the action of the gyroscope.

What was learned: What principle explains the stability of the gyroscope? Why does it resist falling and turning?



A radio beam is sent from the plane to the earth, and is reflected by the earth's surface. Accurate devices measure the amount of time required for the echo to return to the ship and indicate altitude on a dial on the instrument board.

Exercise. *Complete the following sentences:* The airplane engine is a —1— cycle, —2— combustion type engine. At high altitudes more air is supplied to the engine by the —3—. The engine is —4— cooled in smaller and low-altitude planes, and usually —5— cooled for high-altitude and larger planes. The standard airplane wing system today is the —6—. The —7— is the body of the plane. Airplanes are turned right or left by the —8—, up or down by the —9—, and held level by the —10—. The use of —11— beams permits automatic control. A device for measuring altitude is the —12—.

8. How do the railroads provide transportation?

While we are more familiar with the automobile and more impressed by the speed and novelty of the airplane, the trains roll along, doing the greater part of the transportation work of the nation and attracting little attention.

What problems must railroads solve? A railroad consists of the road itself, the trains of cars and engines, the signal and control equipment, and stations, yards, business offices, and other equipment necessary to handle freight and passengers quickly and economically. Each of these introduces problems. The road must be maintained in good repair, grades must be made safe, crossings must be protected, and bridges and tracks must be guarded against accident. As trains wear out, they must be replaced by more efficient

Courtesy New York Central System

This fully streamlined steam train was running at 70 miles per hour when this picture was taken. Note the drive wheels of the locomotive and the smooth connections between cars.

rolling stock (cars and engines). Arrangements must be made to move freight quickly to and from the train.

How is the track laid? Improvement of tracks is the first step toward increasing the efficiency of railroads. The railroad track is made of wooden crossties which support steel rails. The ends of the rails are joined by plates bolted in place. Experimental tracks are being made with the rails welded together to eliminate the vibration produced when wheels pass from one rail to another. The rails are spiked to the crossties. The crossties, treated with creosote, are laid on a roadbed of rock, gravel, packed earth, or sand.

To attain the smallest possible grade, railroads follow rivers through hilly or mountainous country. Railroads must be made almost level.

Tracks are constantly patrolled for safety. Elaborate electrical signal systems provide the control which prevents trains from colliding with each other and which protect crossings.

There were, in one recent year, 240,000 crossings where roads cross railroads. Until these crossings are eliminated, it is impossible for trains to compete with airplanes for speed. There are three ways of handling the problem, which must be worked out by the railroads and the public together.

Courtesy New York Central System

Travel by railroad is safer than by any other means, largely because of the great care used in maintaining tracks and in controlling movement of trains by signals.

First, all necessary crossings for heavy traffic must be separated by overpasses or underpasses, which cost about $25,000 each. Second, all necessary crossings for moderate traffic must be controlled by signals, and the public must be taught to obey the signals. Third, all the unnecessary crossings must be eliminated.

How do the passenger trains operate? Today it is possible for a person living in Chicago to spend a week end in Denver and be back in time to go to work Monday morning. The world's fastest long-distance passenger run is between these two cities. The time required is only 16 hours. Train speeds of a mile a minute are common, and speeds of 100 miles an hour are possible over short distances in level country.

A passenger train accommodates from 75 to 500 people and can be run for a cost of from 60 cents to $2.00 a mile. Fares range from one cent to 3½ cents a mile. The economy of the train compared to that of an automobile is considerable, unless four people ride in the automobile.

Trains have safety records which are far superior to those of either airplanes or automobiles. One is a hundred times safer in a train than in an automobile.

The new trains have attained their outstanding service in several ways. Streamlining, the most spectacular of these, was done to catch the fancy of the public as well as to increase the economy of operation. Trains have been made much lighter in weight, which is more important than streamlining. Old trains were made up of locomotives weighing as much as 300 tons and cars weighing as much as 80 tons. The first of the streamliners weighed only 85 tons complete, including the engine and three cars. More recent streamliners are heavier but not nearly so heavy as the old

trains. Reducing weight decreases losses due to inertia and to overcoming gravity on grades.

The trains have been made more comfortable by eliminating looseness of couplings. The cars now start smoothly, instead of in a series of jerks. The springs are improved. The air-conditioned cars are free from smoke, dust, and oily soot. The double windows and wood-fiber insulation reduce noise in the train. Radios, low-priced meals, and comfortable seats are featured to make travel more pleasant.

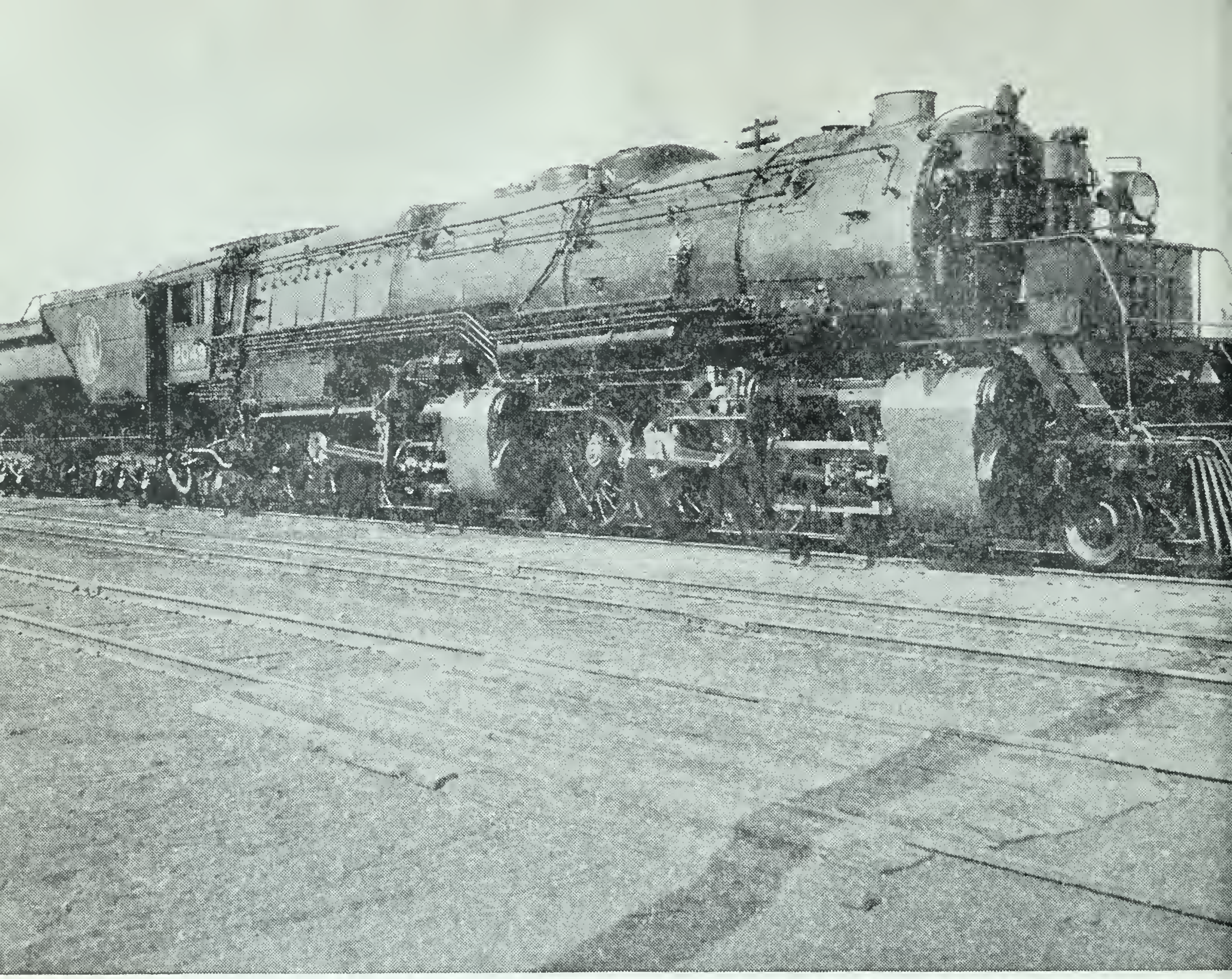
Power is provided by either steam engines or by Diesel-electric locomotives. Boiler pressures of 300 pounds per square inch, which produce steam temperatures of about 425 degrees Fahrenheit, are used to drive steam engines.

The Diesel-electric engine is economical to run but expensive to build. The first streamliner using this combination cut operating costs to one-third of the former steam costs. The Diesel engine operates a dynamo in the power car, and the dynamo provides current for motors which turn the wheels. This makes possible the smoothest, most flexible of all power units. The cost of such units is the only obstacle to their general use. At present it seems that steam will be used for large trains and long runs, while the smaller Diesel units will be used for local runs and smaller trains.

At present, the railroad train offers the safest, most economical, most certain, and most comfortable means of travel for long distances. It is exceeded in speed only by the airplane.

How do freight trains operate? The most important part of the national system of transportation is the freight train. It has been estimated that almost every workman in the United States would be employed in driving, care, and operation of trucks, if it were necessary to haul all the nation's freight by automobile. While this estimate may be exaggerated, it illustrates the importance of the freight train.

For every dollar obtained from passenger fares, the railroads take in six dollars from freight. Freight cars move livestock rapidly enough that a steer from Montana arrives in Chicago in good condition. Oranges from California, Texas, and Florida are deposited safely in New York in spite of heat in the South and freezing in the North. Iron ore moves



Courtesy Great Northern Railway

The heavy work of hauling freight is performed by powerful steam engines. Locate the two engines, the drive wheels, and the engineer's cab.

by train from the Iron Ranges of Minnesota to the freighters of the Great Lakes and down by boat to Detroit, Gary, and Chicago. Lumber from the Pacific Coast is used in houses in Indiana. Manufactured articles produced in New England and New York are standard supplies on the store shelves of Oregon and Georgia. Freight trains make possible all these necessary results.

Freight traffic is improved by increasing the power of the engines and by decreasing the weight of the trains. There are in use 1,400,000 freight cars. Reducing the weight of these cars six tons each would cut the cost of hauling freight 150 million dollars a year. It is believed that new steel alloys will make it possible to reduce the weight of hopper cars in which coal and ore are hauled from 50 tons to 25 tons.

Freight cars are being made small enough that the body of the car and its contents can be loaded onto truck trailers from the railroad carriage and conveyed directly to stores and warehouses. It is much more economical to haul heavy freight for long distances by train than by truck.

How will the railroad of tomorrow operate? Our railroads are so essential to national welfare and to national defense that we must keep them in best operating condition. Future trains will be lighter in weight; engines will be more powerful; Diesel trains will run on faster, more frequent schedules; and roadbeds will be straighter and more nearly level. There will probably be fewer grade crossings, and trains will be even safer than they are today.

Courtesy The Milwaukee Road

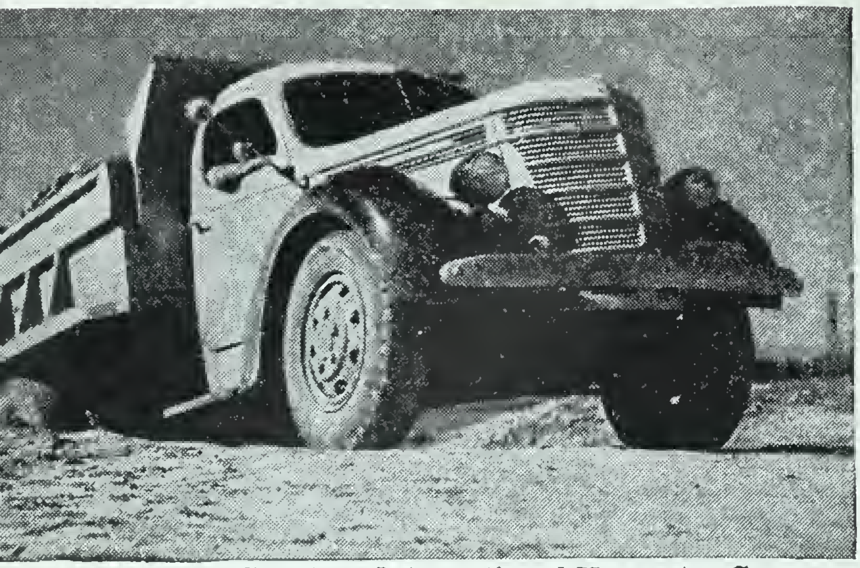
One of the best trains to the West is pulled by this powerful electric locomotive. Where water power is abundant, as it is in the Rocky and Cascade mountain regions, electricity is a satisfactory source of power.

Filmstrips: Freight. S.V.E.
Passenger trains. S.V.E.

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* gravity, inertia, streamlining, air resistance, friction, air conditioning, Diesel, freight, lightweight, alloys, crossties, safest, economical.

Science activities. 1) If the pupils have never ridden on a streamlined, air-conditioned train, arrange to have the class visit such a train. Your railroad station agent will let you know when it is possible.

2) Count the railroad crossings in your community over which the traffic is so light the crossings could be closed. How many crossings are there where people trespass on the railroads at the risk of their lives?



Courtesy International Harvester Co.

Local hauling by trucks is an important part of our national transportation system. Trucks are powerful, rugged, and adapted to short hauls and frequent stops.

9. How is local transportation handled?

There are four major devices which provide for local hauling and transportation: the truck, the bus, the streetcar, and the tractor.

How is the truck best used? There are two kinds of trucks: gasoline trucks, which are usually small, and Diesel trucks, which are usually larger than 3½ tons. The local delivery services of bakeries, silk stores, and floral shops are sometimes handled by electric trucks driven by storage-battery motors. The absence of odor in electric trucks is considered an advantage in handling delicate goods.

The gasoline truck differs from the automobile only in the size and power of the parts and in the body. The gear ratio is usually different in trucks—that is, the gears give more power and less speed than do the gears of the automobile. Only in light delivery trucks, mounted on a passenger automobile chassis, is the gear ratio the same as for the automobile.

The Diesel truck is standard for all heavy hauling and is most efficient in the larger sizes. The Diesel engine is more efficient than the gasoline engine because it operates at higher pressures and burns fuels which are cheaper than gasoline.

Trucks may either have the body attached to the truck itself, or the truck may be divided into tractor and trailer. The word *tractor* is used to describe any machine which is used for pulling, as well as the special tractor used for farm and construction work. The trailer is usually mounted on two pairs of wheels, with wide tires to support the load.

Large trailers carrying 8 to 12 tons are so high and wide that they make passing difficult and reduce visibility of the road far below the required 400 to 600 feet minimum. To

Courtesy Caterpillar Tractor Co.

For the heaviest local hauling, tractors are employed. These three huge logs are on their way to a sawmill to become lumber.

avoid traffic, much of the trucking is done at night when the traffic hazards are greatest because of low visibility. Truck drivers are generally much more skillful than ordinary drivers of passenger vehicles.

In the more populous regions, many road planners consider that it is advisable to provide separate roads for truck and ordinary traffic. Many large cities have certain streets designated for truck traffic.

How is the tractor used? The chief difference between a truck and a tractor is in the way the load is carried or pulled. A truck generally supports part of its load, while a tractor pulls it along. The tractor is used for plowing, for construction, for carrying and providing power for large shovels, for logging operations, for operating winches (a wheel-and-axle machine) and compressed air machinery, and for almost any other use for which a portable power plant is required.

The tractor is essentially the same as a truck. Some tractors do not have batteries but operate from a magneto, which is a dynamo equipped with permanent magnets. The current for the spark is provided by cranking. A tractor

operates under a heavier load than does an automobile. When a tractor pulls a set of plows, it encounters as much resistance from friction as is encountered by an automobile climbing a steep hill. Automobiles climb steep hills in low or intermediate. The tractor's high gear is about equal to the automobile intermediate. The tractor is so short that the gears driving the rear wheels may be operated directly from gears connected with the clutch.

Tractor drive wheels may be of three types. The ordinary rubber-tired automobile wheel is used in much farm work and for operations which require movement over paved or treated roads. The most modern tractors have comfortable cabs and are geared to make speeds of 40 miles an hour.

The second type of wheel is a high, steel wheel with lugs—pieces of metal at right angles to the direction of the wheel movement. These wheels are used in places where the wear on tires would be excessive and where the tractor is used more for a source of power than for pulling.

A third type of tractor lays tracks as it moves along. Each track passes over two or more wheels, which are equipped with gear teeth. The track is really a chain gear, with metal plates and lugs on the side which comes into contact with the ground. The track passes over rollers to support the weight of the load. The tractor may be steered either by having the two tracks operated by separate power transmitting systems, so that one can move faster than the other, or by having a pair of wheels in front. This type of tractor can turn in a small area. The use of the track-laying, or caterpillar, tractor for army tanks shows its great ruggedness and adaptability to travel over rough ground.

Where is the bus best used? The bus is the most common public conveyance in many cities and small towns, and in many cities it provides the only street transportation. Busses are usually made on the same type of frame and have the same type of engines that are used for trucks. Many busses are Diesel-driven.

The chief advantage of the bus in transportation is its convenience. It does not compare with the good trains in comfort or speed and offers only slightly if any greater economy. The bus is more economical than the automobile.

Some attempts have been made to offer transcontinental bus service by air-conditioned sleeper busses. The limited size of busses makes this service less satisfactory than train service.

Courtesy Street Railways Advertising Co.

In smaller cities and in less densely populated sections of large cities, street transportation is provided by bus. Busses may have gasoline or Diesel engines or electric motors as a source of power.

Why is the electric streetcar used? The first street railway in the United States was constructed in 1885, only 56 years after the first locomotive was operated in this country. The electric street railway is being replaced by the bus because of the greater weight of the streetcars and because of the cost of laying tracks upon which taxes are paid. Busses can pass each other and don't require switching.

The streetcar, or trolley, is driven by electric motors. Electricity may be supplied to the car in three ways: from an overhead cable, from a cable laid underground, or from a third rail laid beside the track. Electricity may also be provided by the Diesel-electric system within the car itself.

The motorman operates the car by a controller which regulates the flow of current. The direction of the car, as well as the speed, may thus be controlled. The car is started gradually by admitting the current through resistance coils and by connecting the two motors—first in series, then in parallel.

A million-dollar experimental streetcar has been developed and put into successful use. It has the desired modern transportation conveniences—quick pickup, conditioned air, improved springs and bearings, quiet operation, and a streamlined body.

The street railway has many good features. It carries from 30 to 40 people in the street area occupied by two or three automobiles and need not be parked. It is much safer and more economical than the automobile.

Why are elevated and subway railroads used? New York and Chicago have elevated and subway systems. The ele-

Courtesy Street Railways Advertising Co.

The New York subway runs beneath the streets, buildings, and rivers of the downtown section. In the suburban areas the subway trains run aboveground.

vated railway is being abandoned as rapidly as possible because of the noise, space occupied, and congestion caused by the track supports. The subway is finding increased favor, and as rapidly as money is obtained, railroads entering large cities are being put into underground tunnels. The subway trains run about 30 to 35 miles an hour, but this speed is far greater than is possible by busses in street traffic. A streamlined 100-mile-an-hour train is being developed to carry people from far suburbs into the city.

For what are pipe lines used? While pipe lines are hardly considered transportation systems, they carry 8 per cent of the nation's freight in the form of gas and oil, and take away from other carriers part of their work. Usually welded sheet steel pipes are used. Some pipe lines are hundreds of miles in length and are essential to providing fuel to cities.

Is the horse still used? The horse and mule are still superior in many ways to motors for power. On many farms of less than 160 acres the horse is more economical than a tractor. In towns and cities horses are still used for delivery of milk, bread, and other materials which require many stops and short hauls. The mule is superior to the horse in withstanding heat and poor working conditions.

Exercise. *Complete the following sentences:* The larger trucks usually employ the —1— engine which burns —2—. The truck divided into two parts becomes a —3— pulled by a —4—. Tractors are like trucks except that they have no —5—. Tractor wheels run on —6—, —7—, or —8—. The speed of streetcars is controlled by current flowing through —9— coils. The streetcar is better than the automobile because it is —10— and need not be —11— on the street.

10. How are boats used in transportation?

Boats are of considerable use on inland waters and are the only adequate means of transportation across oceans. Almost a fifth of the freight moving between cities is carried by boat. Boats range in size from the tiny duckboats used by hunters to the giant ocean liners which are able to carry the population of a small city.

Why do boats float? The weight of a boat must be less than the weight of an equal volume of water. Fresh water weighs 62½ pounds per cubic foot; salt water weighs slightly more. A boat will float if it weighs less than this. The weight of an iron boat is only the weight of the iron. The volume of the boat, if it is kept right side up and empty of water, is the volume of the iron plus the volume of the air inside the boat. The air space reduces the density of the boat.

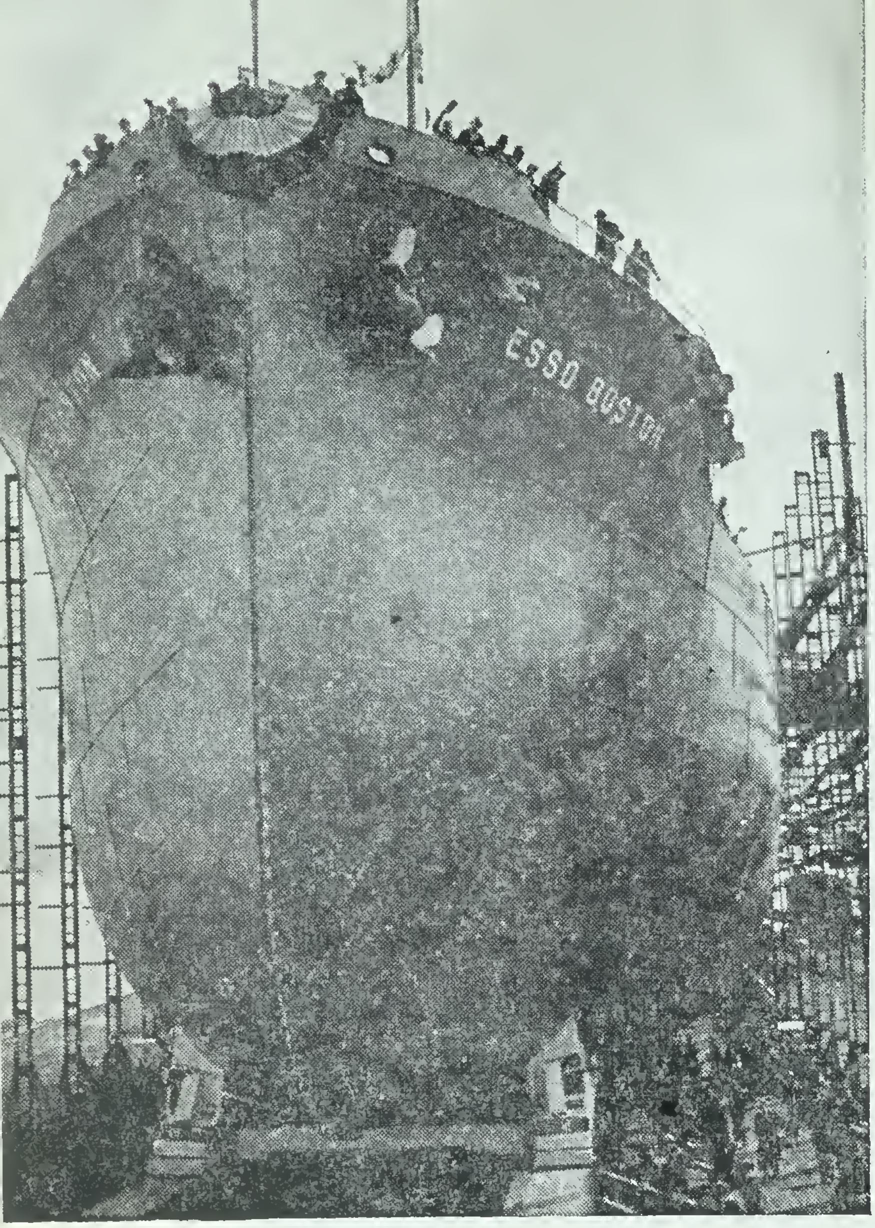
If you make a boat by folding a sheet of aluminum foil, it will float. But if you crumple the aluminum foil into a ball and throw it into water, it will sink. You reduce the volume by rolling the foil into a ball.

Density, as you know, is the weight of a material for a given unit of volume. The density of water is one. In the metric system one cubic centimeter of water weighs one gram. If a cubic centimeter of another material, stone for instance, weighs 3 grams, its density is three. Density equals mass over volume.

In the English system we must do more work to measure specific gravity, which amounts to the same thing as density. If a cubic foot of water weighs 62½ pounds and a cubic foot of another material weighs 250 pounds, we divide 250 by 62½ to find the specific gravity of four.

$$\text{Specific gravity} = \frac{\text{Weight of the object}}{\text{Weight of an equal volume of water}}$$

Boats are so built that the center of gravity is low. The center of gravity is the point around which the weight is equally distributed. If the center of gravity were above water, the boat would have a tendency to roll; and if it were much above water, the boat would roll over, and possibly would sink.



Courtesy Federal Shipbuilding and Dry Dock Co.

Boats are built on tracks and launched by sliding them down the track into the water. This picture shows the shape of the hull and the method of joining plates by riveting.

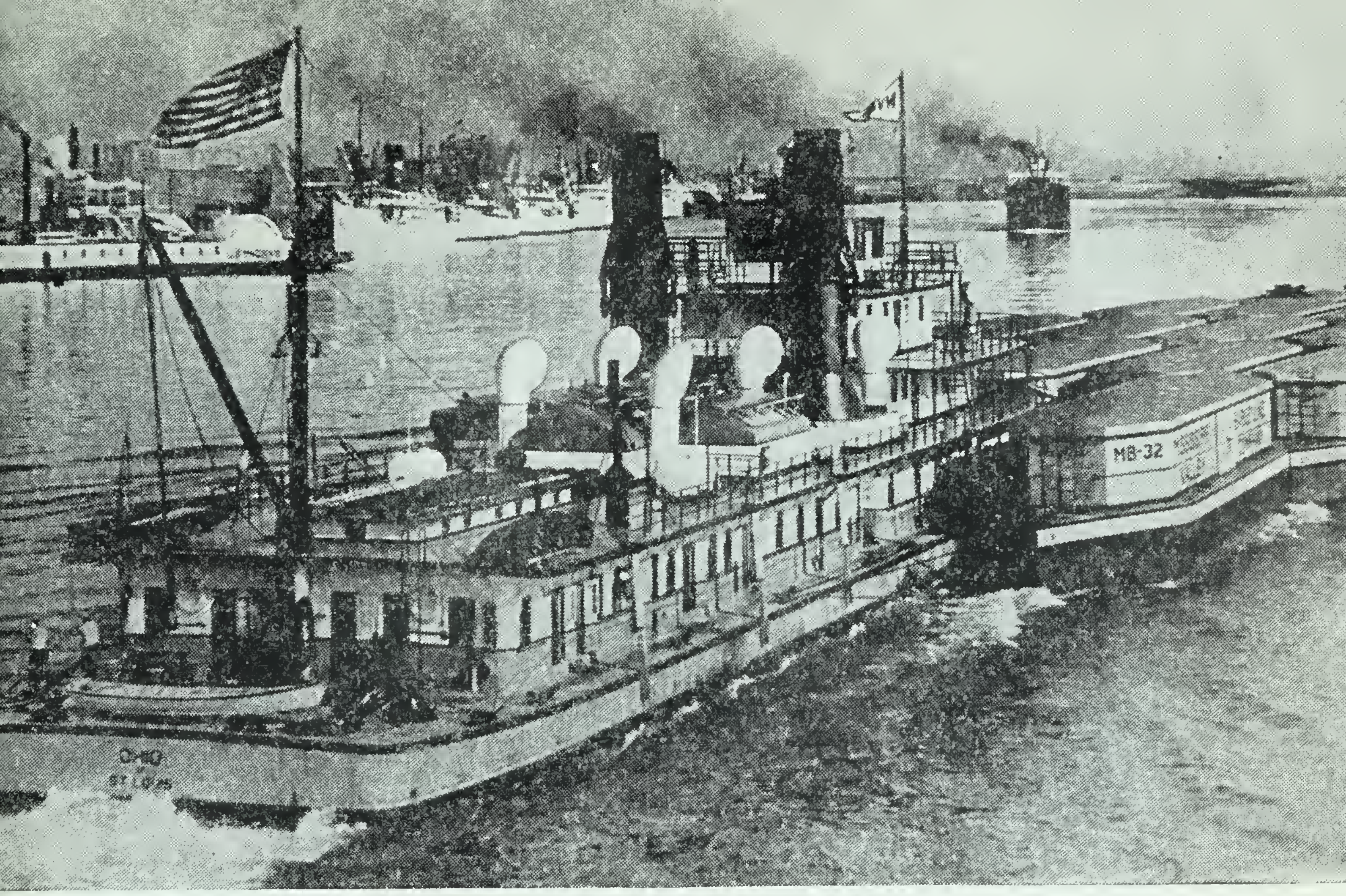
What is a liner? A liner is a large boat which maintains a regular ocean route. The size of ships is rated in tons of displacement. The largest liners displace around 50,000 tons of water, the smaller ones about 10,000 tons. Liners range in length from 400 to 900 feet.

The liner is made of a steel frame and covered with a riveted steel hull. Inside the boat are many compartments. The power is obtained from either steam or Diesel engines. The most advanced type of steam engine has an oil-burning furnace to generate the steam which supplies power to the turbines. These turbines may be from two to six in number. Special turbines must be provided for backing up, for a turbine cannot be reversed. The rotating parts of the largest turbines weigh more than 100 tons. Some boats have steam engines of the triple-expansion type instead of turbines. Sometimes steam escaping from the engine is passed into a low-pressure turbine.

Some steam boilers are fed pulverized coal instead of oil. The coal is blown into the fire.

The funnels of the bigger liners are of no use whatever. Oil burners do not require funnels of this type. More than half the smaller boats are powered with Diesel engines.

Boats are driven through the water by a screw-type propeller, which is made of an alloy resistant to the action of salt water. The propeller usually has three removable blades. Thus if one blade is broken, it may be replaced without re-



Courtesy Dravo Corporation

The larger rivers of the United States provide waterways for movement of freight. This river steamer is pushing loaded barges on the Mississippi River.

moving the entire propeller. The propeller and rudder are placed at the stern or back of the boat.

From 20,000 to 50,000 horsepower are required to operate the larger liners at speeds of 15 to 25 knots. A knot is 6080.20 feet per hour. How many miles an hour do ships travel?

What are tramps and freighters? A tramp is a steamboat which has no regular schedule but takes whatever freight is available and maintains a schedule that suits each voyage. Ocean-going tramps average about 350 feet long and have a displacement of about 3000 tons. They are particularly interesting while loading and unloading because of the winches, derricks, engines, and coils of rope which are used for handling freight. Tramps maintain an average speed of about 9 knots. Most tramps are driven by Diesel or regular piston-and-cylinder steam engines.

The hold, or hollow part, of the boat is designed to carry freight. As much space as possible is made available for goods—lumber, grain, chemicals, fibers, tar, iron, cattle, or whatever may be picked up.

Great Lakes freighters and ore boats average from 450 to 600 feet in length and have a displacement of 15,000 to 20,000 tons. The advantage of shipping by water is the low cost made possible by the low resistance of water to boats. It is not necessary to build roads or tracks for boats.

What are trawlers and tugs? A trawler is a fishing boat, between 75 and 150 feet in length, that drags a net through the water. These boats also transport fish from slower fishing boats to the land as fish are caught. They usually are driven by triple-expansion steam engines.

A tug is a small but very powerful boat. It is practically all engine and hull. The larger tugs are from 1000 to 1500 tons, and the smaller are scarcely larger than motorboats.

Tugs have two main uses. They push, tug, and pull liners to bring them to their docks. The liners are so large that they cannot move safely under their own power in harbors. Four or five tugs can move most liners. Tugs also move barges, which are flat shells of steel used to haul coal, wheat, ore, garbage, fish, or almost anything that can be moved by boat.

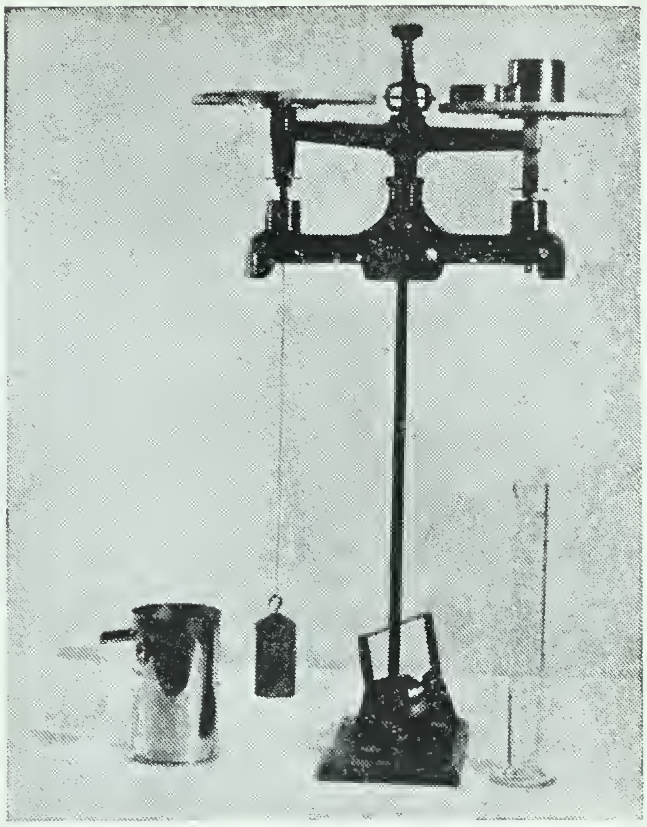
What other boats are used? Many old paddle-wheel boats are in use as excursion steamers or for short freight hauls. Many small, gasoline-driven boats on the inland waters are of value for sport, transportation of a few passengers, and for fishing. Ferries are used in a number of places where bridges are not practical.

What is navigation? Navigation consists of the work of determining the course and location of a boat. The position of a ship is measured in relation to the sun and stars when they are visible.

Dead reckoning is used when weather is cloudy. Dead reckoning is the estimate of the ship's position by use of a compass and of a record of the ship's speed. It is influenced by currents and winds and is not accurate. There are two types of compass in use: the ordinary compass and the gyrocompass.

Maps and charts are necessary for navigation. The charts include such data as the angle of the sun above the horizon at different seasons, means of calculating position, and correction of the compass reading to find true north.

Traffic lanes are established separating east- and west-bound traffic in the North Atlantic. Iceberg patrols warn of danger from ice. Radio signals assist the ship's officers in forecasting weather and in estimating probable drift from the wind.



This is one type of apparatus that may be used to perform the demonstration.

Demonstration. How Is Specific Gravity Measured?

What to use: Weights, block of wood, balance, jar, pan.

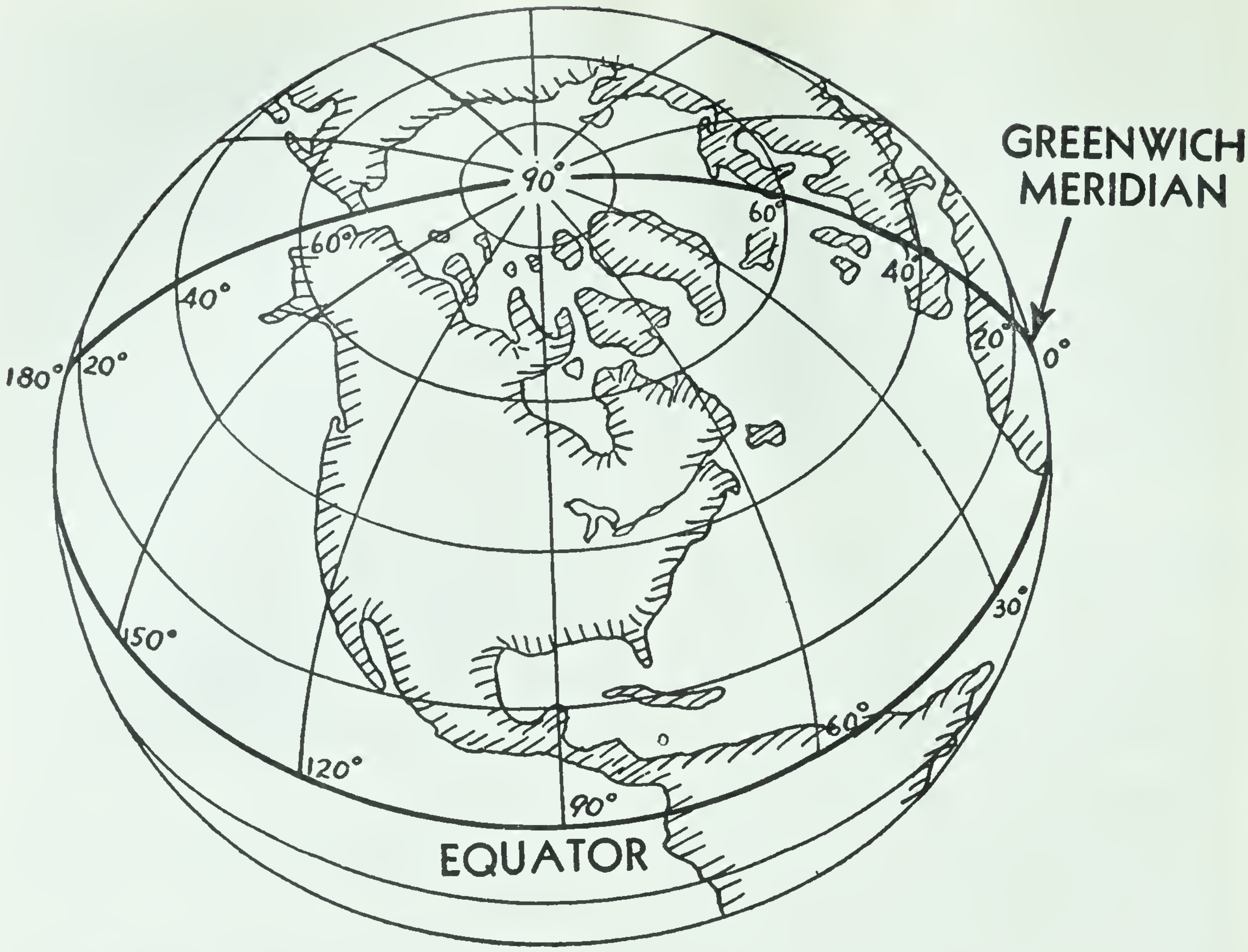
What to do: Weigh carefully the block of wood. Fill the jar completely full of water, first placing the jar in the pan. Carefully float the wood in the jar, catching the water that overflows. Weigh the water.

Repeat the experiment, filling the jar as before, but lowering a large weight into the water with a spring balance. Note the reading of the spring balance before the weight touches the water and after it is completely covered. Then again weigh the water in the pan.

What was observed: Make a record of the weights of the block, the water, and the weight. What does the block weigh in water? The weight? How much weight did the block lose? To find the specific gravity of the weight, divide its weight by its loss of weight.

What was learned: Is the loss of weight in an object in water equal to its own weight in air or to its loss of weight in water?

Exercise. *Complete the following sentences:* A floating object displaces its own —1— of water. Water weighs —2— pounds per cubic foot. Hulls of large ships are made of —3—. The specific gravity of water is —4—. The loss of weight of an object in —5— equals the —6— of the water displaced. A small boat used to move liners is a —7—. The largest liners have a displacement of about —8— tons. The fastest boats travel about —9— miles an hour.



Longitude is measured from the Greenwich meridian.

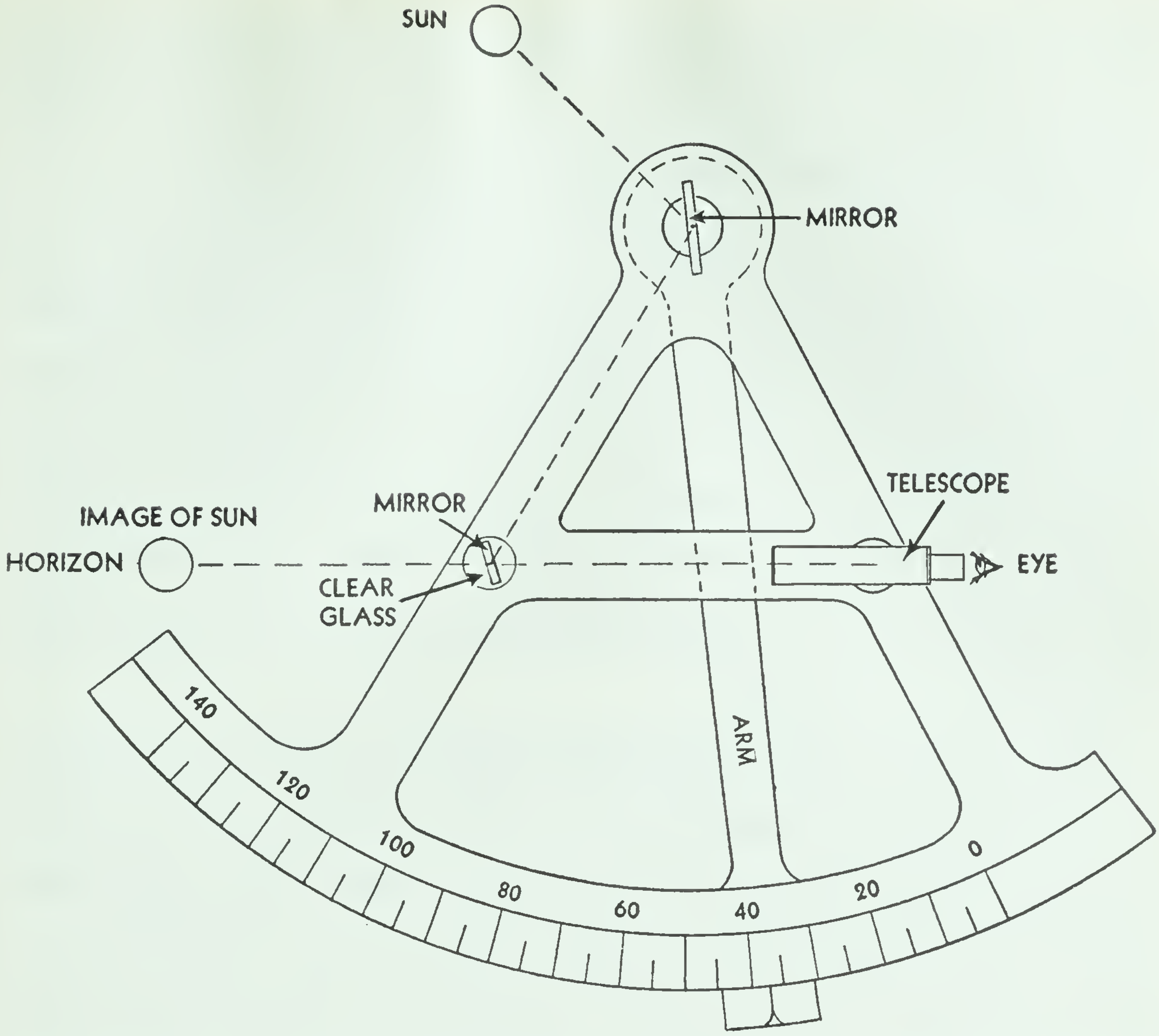
Science activity. Make a Cartesian diver. Use reference books to find out what it is, how to make it, and why it works.

11. How does transportation depend upon astronomy?

The necessity of knowing the exact time and the accurate location of airplanes and boats has increased greatly the use of astronomical observations.

How do we find the exact location of places? Simple methods of locating places, such as locating direction by the sun or North Star, are not sufficient for transportation. If a ship in distress sends out an SOS. call for help, the exact location of the ship must be given. Places anywhere on the earth are located exactly by giving their latitude and their longitude.

Latitude is the distance in degrees north or south of the equator. Any line drawn around the earth is a circle. Hence latitude is measured in degrees (°). There are 360 degrees



The sextant is an instrument used to determine latitude on board ships.

in a circle. A degree is divided into 60 minutes (′), and a minute is divided into 60 seconds (″). All points on the equator have a latitude of 0 degrees. The poles have a latitude of 90 degrees. Points between the equator and the poles have latitudes ranging from 0 to 90 degrees. The city of Minneapolis, Minnesota, has a latitude of 45 degrees. It is halfway between the equator and the North Pole. A circle drawn on the earth parallel to the equator is called a parallel of latitude. All places on the same parallel have the same latitude.

In addition to latitude, longitude must also be known in order to locate a place exactly.

Longitude is the distance east or west from the prime meridian that runs through Greenwich, England. A meridian is an imaginary line that extends from pole to pole. In meas-

uring longitude, the Greenwich meridian is called zero degrees; a point on the opposite side of the earth is 180 degrees. Intermediate points have longitudes ranging from 0 to 180 degrees east or west according to their location.

At the equator a degree of longitude equals 69 miles. A second equals about a fifth of a mile. By knowing the exact latitude and longitude, it is possible to locate a ship within a few hundred yards. As one goes north from the equator, the length of the degrees of longitude becomes shorter, and it is possible to locate a place with even greater accuracy. From a map find the latitude and longitude of your own city.

How is latitude found at sea? In order to find latitude, sailors use an instrument called the sextant. It is used to find the height of the sun above the horizon at noon. This height is expressed in degrees.

The sextant is pointed toward the sun at noon. As shown in the diagram, the light from the sun strikes the mirror, from which it is reflected to another mirror. On its way, the light passes through dark glasses which reduce the glare so it will not hurt the eye. One half of the second glass is a mirror, the other half is made of clear glass. As a person looks through the telescope, he sees two things: the image of the sun, which has been reflected by the mirror half, and the horizon, through the half that is made of clear glass. The arm of the instrument is moved till the image of the sun just touches the horizon. The angle is then read from the scale at the bottom of the instrument. This angle is the height of the sun. From this angle, and by using tables which the sailor has on hand, the latitude of the place may be found.

How is longitude found at sea? The longitude of a place may be determined by comparing its solar time with the solar time of Greenwich. A difference of one hour equals a difference of 15 degrees longitude. For example, when it is six o'clock in the morning at Chicago, it is twelve noon at Greenwich. Multiplying this difference of six hours by 15, we get 90 west longitude for Chicago.

In order to find longitude at sea, ships carry two clocks. One is set to keep Greenwich solar time. It is called a chronometer [krȯ·nŏm′ė·tẽr]. The other clock keeps local solar time. This clock is kept accurate by making observa-

tions of the sun. The longitude is determined by finding the difference in time between the two clocks. For example, if the Greenwich time is 2 P.M. and the ship's time is 1 P.M., then the difference in time is one hour. One hour's difference in time equals a difference of 15 degrees in longitude. The ship is located at 15 degrees west longitude.

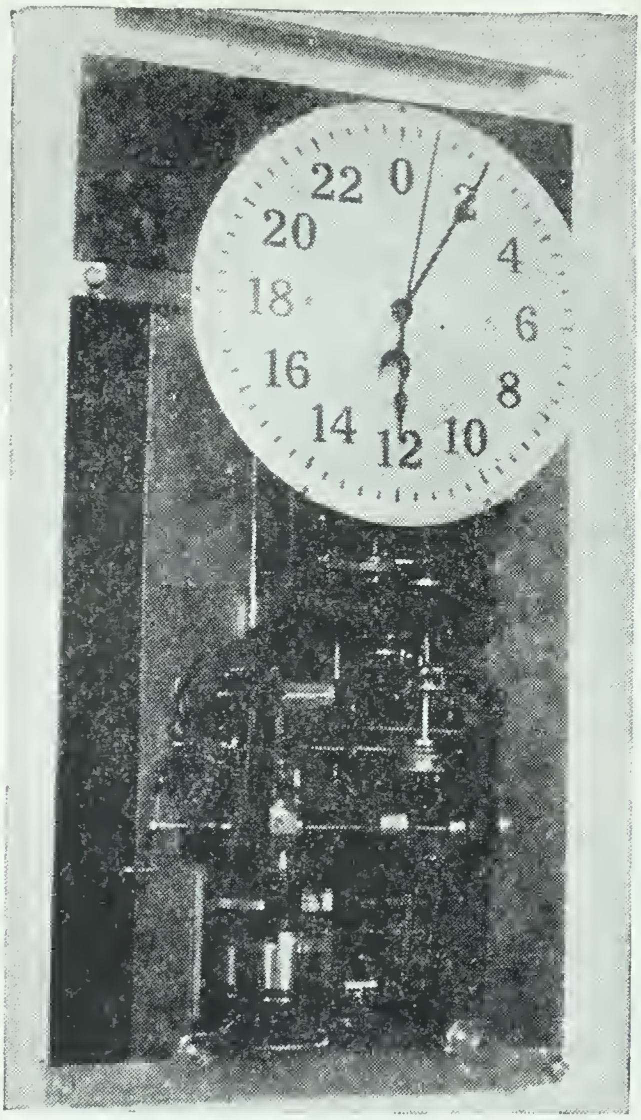
What is time? Measurement of time is based on the daily rotation of the earth. The day is divided into 24 hours; each hour is divided into 60 minutes; and each minute is divided into 60 seconds.

There are two ways of determining when the earth has completed one rotation: by observing some star or by observing the sun. The time obtained by observing a star is called sidereal [sī·dēr′ē·ăl] time, that obtained by observing the sun is called solar time.

How is sidereal time determined? The observations in this country are made at the Washington Naval Observatory, which is owned by the United States Government. The observations are made by means of a small telescope, so mounted that it turns only from north to south. It can be made to follow the meridian and is used to determine when a star crosses the meridian. Because this crossing of the meridian is called a transit, the telescope is called a transit instrument. The telescope is housed in a small room in which there is a long narrow opening to the sky, extending north and south.

The telescope is pointed toward a certain point in the sky, and the exact time is taken when a certain star is seen in the telescope. Twenty-four hours later the same star is observed again. And when it again crosses the meridian, that is the end of a sidereal day. The standard clock in the observatory is then set to correspond with this time. Sidereal clocks are numbered from 1 to 24, instead of from 1 to 12.

What is true solar time? When observation is made of the sun to determine when the earth has completed a rotation, the result is known as a solar day. This day is about four minutes longer than the sidereal day because at the same time that the earth is rotating, it is also revolving around the sun. In a day the earth has moved a little way in its orbit around the sun.



Courtesy U. S. Naval Observatory

The automatic time-signal apparatus sends signals by telegraph. The clock indicates 24 hours instead of 12.

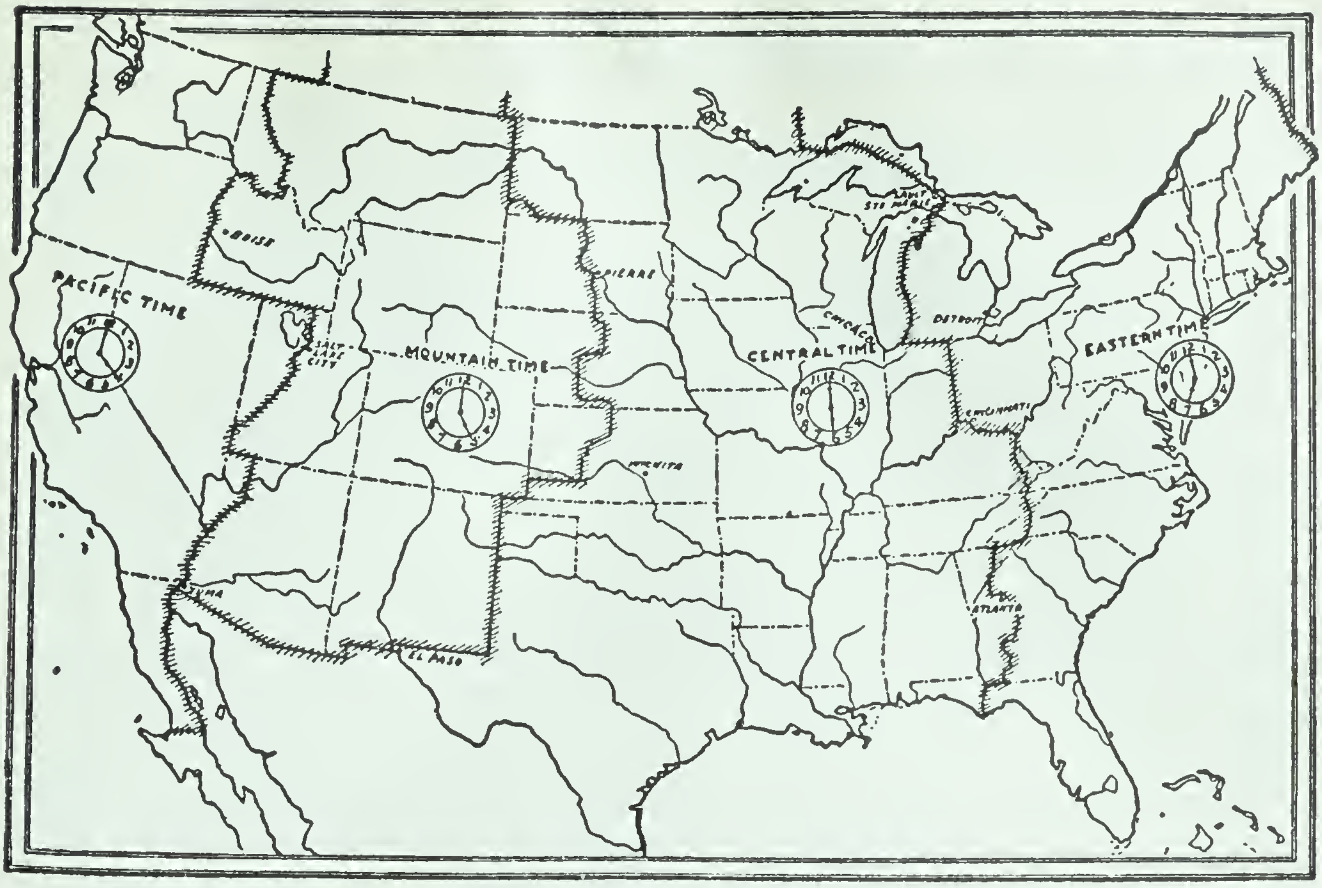
Because the transit of a star can be more exactly observed than that of the sun, the observers at the Washington Naval Observatory first find the sidereal time. This is easily changed to the mean solar time. The correct time is then sent out to the country and to ships at sea by means of telegraph and radio.

What is standard time? Since Washington is in the Eastern time belt, cities in the other belts must subtract one or more hours according to their location. Those cities in the central zone subtract one hour; those in the Mountain zone, two hours; and cities in the Pacific zone, three hours. If it is 12 noon in Washington, it is 11 A. M. in Chicago, 10 A. M. in Denver, and 9 A. M. in San Francisco.

Solar time is constantly changing as one travels east or west. When it is noon at one place, it is not noon at places east or west. In the latitude of 40 degrees, a distance of 800 miles east or west makes a difference of an hour in time.

In former days each town had a time different from that of towns east or west of it. When people traveled little, this difference did not cause much trouble. But as railroads were built and people traveled more, this difference in time became confusing. Therefore, in 1883 a system of standard time was adopted.

Now, instead of having hundreds of different times as formerly, there are only four times. In traveling across the country, one must set his watch back or forward an hour as he enters each belt. Traveling from east to west he sets



For the sake of convenience, the boundaries of standard time zones take into consideration location of towns, divisions of transcontinental railroads, and state lines.

his watch back an hour for each time belt; traveling from west to east one sets his watch ahead.

If you live in the Eastern time belt, you may listen to a broadcast in the early evening of a football game being played in California in the afternoon. There is a difference of three hours between the times in the Eastern and the Pacific time belts. When it is 7 o'clock in New York City, it is 4 o'clock in San Francisco.

Exercise. *Complete the following sentences:* A circle has —1— degrees. Latitude is measured from the —2—, longitude from —3—. The clock on which Greenwich time is kept is called a —4—. Latitude is found by use of a —5—. Time measured from a star is called —6— time. A —7— time belt is —8— degrees wide. One sets his watch —9— when traveling east.

Science activity. The latitude of a place is the same as the altitude of the North Star above the horizon expressed in degrees. You will need two straight lines to determine the angle. One is a horizontal line; the other is a line pointing to the North Star. Work out a way of finding these two lines and measuring the

angle they make. Compare your results with the latitude of your city as expressed on a map of your state.

A Review of the Unit

The scientific laws on which transportation is based are the laws of motion and the laws of conservation of energy. An object at rest remains at rest, and an object in motion continues in motion in the same straight line unless acted upon by an outside force. Change in the rate of motion is in proportion to the force causing the change. For every action there is an equal and opposite reaction. Gravitation is the attraction of every object in the universe for every other object. Energy cannot be created or destroyed, but mechanical energy may be lost when changed to heat energy. Energy is released by chemical or physical changes and when controlled will do work.

An exercise in thinking

Match the principles and related ideas, according to the directions given in the review at the end of Unit I.

List of principles

A. A body at rest remains at rest, and a body in motion continues in motion in the same straight line, unless acted upon by an outside force.

B. The change in rate of motion is in proportion to the force producing the change.

C. Friction changes kinetic energy to heat.

D. Work is done when force overcomes gravity.

E. Air resists objects moving through it in proportion to the square of their speeds.

F. The amount of kinetic energy obtained from engines is in proportion to the amount of heat taken from the gases in the engine.

G. Reaction time is the time between receiving a sense impression and the muscular response to the stimulus.

H. When unequal forces are exerted upon an object, the resulting movement is in the direction of the larger forces.

I. The loss of weight of an object in water is equal to the weight of the water displaced.

List of related ideas

1. Because the Diesel operates at higher temperatures, its efficiency is 37 per cent compared with the gasoline engine efficiency of 25 per cent.
2. The lifting effect of air pressure causes an airplane to fly.
3. Speeding automobiles cannot turn corners rapidly.
4. Streamlining increases the efficiency of vehicles at high speed.
5. It takes from one-third to two-thirds of a second to put on brakes.
6. Brakes become hot when they stop moving trains.
7. Powerful engines are required for quick pickup.
8. Radiators are used to remove heat wasted in the automobile.
9. The airplane propeller is an inclined plane that is pushed forward by the air.
10. Boats must weigh less than 62½ pounds per cubic foot.
11. Some of the energy used in climbing a hill is regained by coasting.
12. It is expensive to stop and start freight trains.
13. Steam engines are made with triple-expansion cylinder arrangements.
14. No human being can safely drive an automobile at 70 miles an hour in ordinary traffic.
15. Tires of racing automobiles sometimes blow out because of heat.
16. Railroad tracks are banked on curves.
17. Speeds of automobiles above 40 miles an hour are not economical.
18. Every projection of a vehicle body slows forward motion.
19. To maintain high speeds, powerful engines are used in boats.
20. The hotter the exhaust gases, the more power is wasted.
21. Road grades are kept below 9 per cent.
22. Roller bearings reduce waste of power in trains.
23. More heat is produced in stopping a train than in stopping an automobile.
24. A pendulum swings upward against gravity until its kinetic energy has been changed to potential energy.
25. Brake shoes wear and must be replaced.
26. Gears are stripped from their wheels if a motor running at top speed is suddenly connected to an automobile standing still.
27. Lubricating oil is used between the parts of vehicles to save energy.

28. Curved roads are dangerous roads.

29. A submarine has a specific gravity of more than one when submerged.

30. An airplane turns sidewise when the rudder is turned to increase air pressure on it.

31. The force of the air on a balloon is greater than the force of gravity.

32. All the useful energy of the airplane engine is used to overcome drag.

33. In streamlined trains the cars are joined without spaces between.

34. Track-laying tractors are efficient because they do not slip.

35. The size of boats is measured by the weight of the water they displace.

36. All human beings are relatively slow thinkers in emergencies.

37. When an airplane has no power, it falls faster and faster to the earth.

38. The upper part of the airplane wing is more sharply curved than the lower surface.

39. Airplanes use more energy than do other devices for transportation.

40. The higher the speed of an automobile, the more frequently fatal the accident.

Some things to explain

1. Why has transportation made faster progress than many other branches of industrial work?

2. Why did the railroads fall behind for a time in competition with automobiles and trucks?

3. Has the automobile driver a right to expect the public to build expensive streets so that he can park on them? How much could be saved by reserving one lot in each block for a public parking space?

4. How is time important in transportation?

5. Comparing the final cost, which is cheaper: to build a railroad which pays taxes, to build a highway from gasoline taxes, or to dredge a river with money from general taxes? Should automobile freight be taxed more than pleasure automobiles?

6. Why is the airplane more widely used than the dirigible?

7. What was the earliest use of steam for transportation?

8. Why are pedestrians responsible for about half the automobile accidents?

Some good books to read

Arnold, H. H. and Eaker, Ira, *This Flying Game*
Baxter, T. and Young, B. M., *Ships and Navigation*
Bock, G. E., *What Makes the Wheels Go Around*
Bryan, L. A., *Aerial Transportation*
Cartwright, C. E., *Boy's Book of Ships*
Compton's Pictured Encyclopedia
Goldstrom, John, *A Narrative History of Aviation*
Gregory, J. W., *The Story of the Road*
Hamilton, J. R. and Thurston, L. L., *Safe Driving*
Harvey, Laura B., *The Skycraft Book*
Hylander, C. J., *Cruisers of the Air*
Jackson, D. H., *Common Sense Driving and Pedestrian Rules, With Rules for Bicycle Riders*
Jackson, G. G., *The Romance of the Railway*
Jackson, G. G., *The Romance of the Sea*
Johnston, S. P., *Horizons Unlimited*
Miller, J. A., *Fares Please*
Peck, J. L., *So You're Going to Fly*
Wead, Frank, *Wings for Men*
Webster, H. H., *Travel by Air, Land and Sea*
Whyatt, H. G., *Streets, Roads and Pavements*

Some interesting motion pictures

Development of Transportation. Erpi (*16 sound*)
Flight of the Century. New York Central Railway (*16 silent or sound*)
Once Upon a Time. Metropolitan Life Insurance Company (*16 silent or sound*)
Ring of Rails. General Electric Company (*16 silent*)
Wings of a Century. Bell and Howell (*16 silent*)
Farther, Faster, and Safer. Pennzoil (*16 sound*)
Story of the Airship. Goodyear Tire and Rubber Company (*16 silent*)
Automobile. Eastman (*16 silent*)
Railroad Safety. Eastman (*16 silent*)
Ocean Liners. Eastman (*16 silent*)
Construction of the George Washington Bridge. Port of N. Y. Authority (*16 silent*)
Air Liner. Bell and Howell (*16 sound*)
New Roads to Roam. Ford Motor Company (*16 sound*)
Safety's Champion. Y.M.C.A. Motion Picture Bureau (*16 sound*)
Follow the White Traffic Marker. U. S. Bureau of Mines (*16 silent*)

Courtesy Western Electric Company

UNIT ELEVEN

HOW DO WE COMMUNICATE WITH ONE ANOTHER?

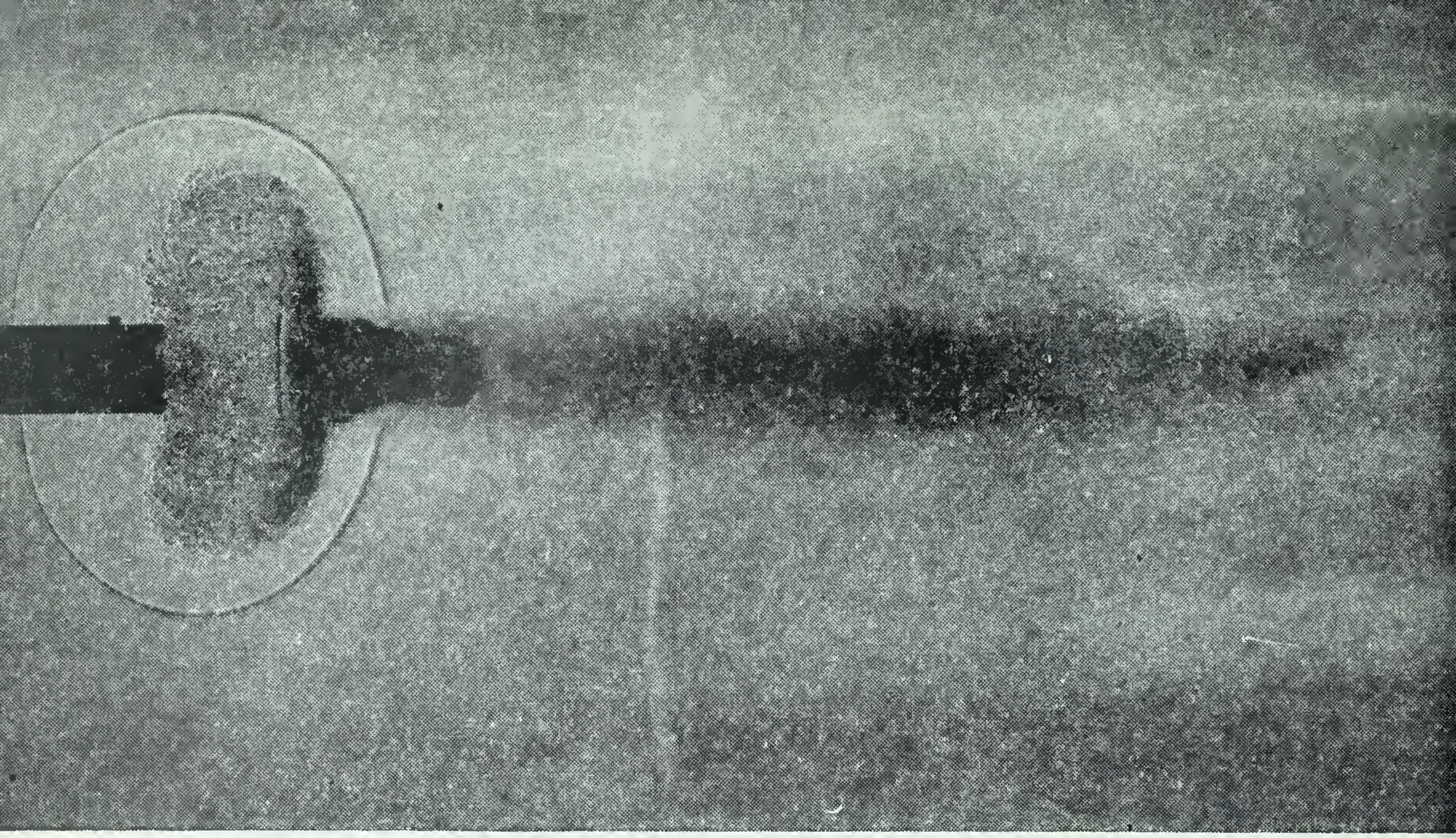
WITHOUT the radio, the telephone, and the newspaper, the world would seem strangely empty. We expect to hear as a matter of course the dramatic programs, the news flashes, the bands, the police bulletins, and the advertising that comes from our radios. When we wish to talk to a friend or order a quart of ice cream from the corner drugstore, we use the telephone. The daily paper is glanced through without our marveling at the pictures that were taken a few hours before in another continent.

We know, when we think about it, that these commonplace results really are wonderful and that they illustrate better than most of our experiences man's amazingly skillful and complex control of energy. We know that it has taken about a hundred years of the most ambitious study in the history of the human race to develop the simple laws of electricity to the point that they can be applied to the problems of communication.

You already know most of the principles on which all the common devices used in communication operate. You recall, of course, that a current can be produced by cutting a conductor with a magnetic field. You may think it strange to learn that the radio waves which travel to your aerial are the same in their effect as a moving magnetic field, and that a tiny current in the aerial is able to control your radio.

You know that every conductor carrying a current is surrounded by a magnetic field, and that the strength of the magnetic field can be changed by changing the current. This simple principle explains the operation of parts of the telephone, radio, and telegraph. Thus you see that, although communication is dependent upon use of complex devices, the principles on which these devices operate are known to you.

Then too, we talk, produce music, and listen to the sounds of the out-of-doors, just as our remote ancestors did. We may try to learn another language in school, but we find that learning a new form of speech is an unpleasantly difficult task. Yet we speak the English language easily because we have become accustomed to it. Our habits of talking and hearing are just as marvelous as are the mechanical inventions that have been developed by man's ingenuity.



Courtesy Peters Cartridge Co.

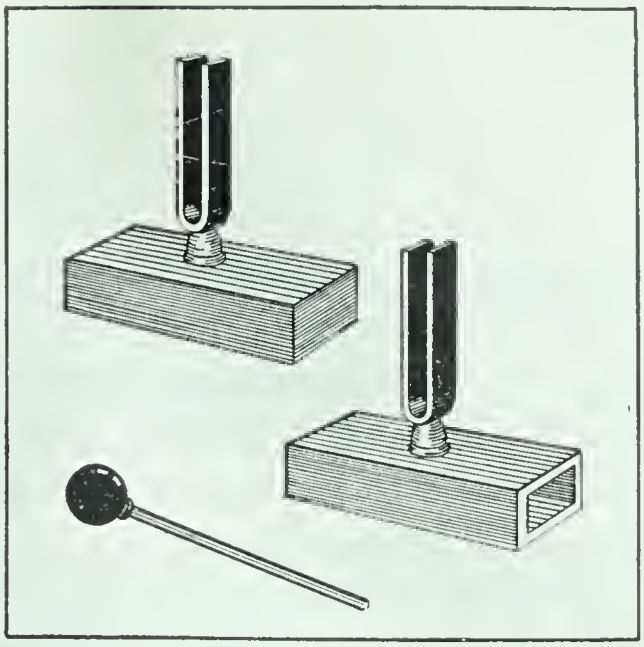
This spark photograph shows a charge of shot leaving the muzzle of a shotgun. The smoke is seen just as it leaves the gun barrel. The "balloon" around the end of the barrel is a sound wave.

1. How do we use sound in communication?

Almost all communication is related in some way to sound. Animals communicate by calling, singing, roaring, or otherwise making sounds. Our speech is based upon the ability of our vocal cords to form certain sounds. Even our thoughts are but sounds which we think out instead of speaking.

What causes sound waves? If you pick up a tuning fork from the table and hold it to your ear, you can hear no sound. But if you strike it sharply against your heel, a sound can be heard. There are several ways of proving that a sounding tuning fork is vibrating. One of the simpler ways is as follows: A piece of glass is smoked evenly. To the end of a tuning fork a fine wire bristle is attached with a tiny drop of solder or wax. Then the tuning fork is held in a clamp and arranged so that the bristle just touches the glass. Next the tuning fork is struck, and the glass moved beneath the bristle. The vibrating bristle scratches a wavy line in the soot. If another bristle is attached to a clock pendulum and caused to make marks on the glass at the same time, it is possible to count the number of vibrations made by the tuning fork in one second.

The sound wave itself is a rapidly moving layer of air molecules which are packed closely together. When photographs are taken of charges of shot leaving a shotgun, one of the sound waves produced by firing the gun appears clearly in the picture and looks like a thin balloon. This "balloon" is composed of molecules pushed close together by the force of the shot. But the molecules themselves do not shoot out from the vibrating object to form the wave. Instead, each molecule moves back and forth in its limited space. The wave is really caused by the molecules of one layer bumping the molecules of the layer next to them and then bouncing back into their places. Those of the next layer in turn bump those of the layer beyond, and so on. Where the molecules are bumping each other there is an area called a condensation. When they bounce back, the air is made thinner for an instant, and this thin layer is called a rarefaction [râr′ė·făk′shŭn].



When one tuning fork is struck, it sets the air into vibration. The air waves are sufficiently strong to cause the second tuning fork to vibrate. If the first fork is stopped, sound from the second can be heard.

Of course a vibrating body does not ordinarily produce only one sound wave and then stop vibrating. Instead waves are sent out at more or less regular intervals. One wave follows another at distances which may vary from two-thirds of an inch to about 70 feet. The distance depends upon the rate at which the waves are produced.

How can we prove that air carries sound? If you stand near a piano and sing a single, loud note, then press your ear against the wood of the piano, you can hear the same note from the piano. The air carried the sound wave to the wire of the piano.

Two tuning forks of the same pitch may be mounted on boxes. If one is struck, you can hear the sound coming from the second fork after stopping the vibration of the first. To

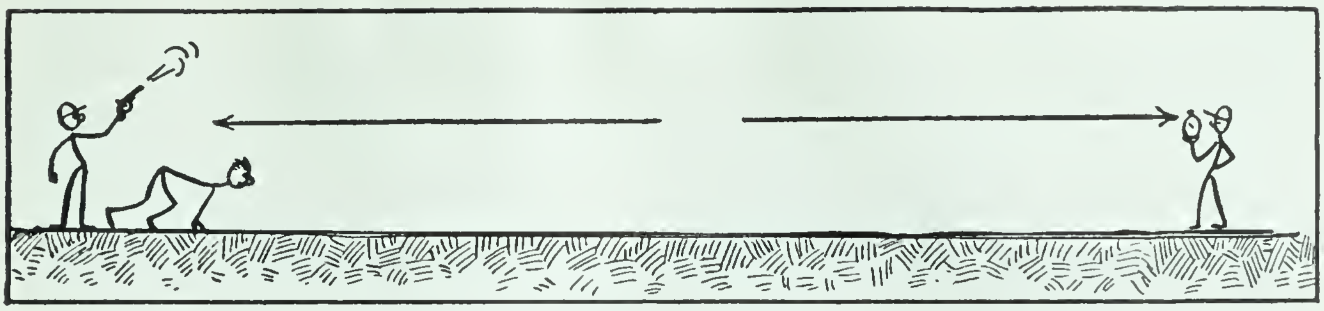
be sure that the sound is carried through the air and not through the table, both forks may be mounted on cords. This experiment will not work unless the forks vibrate at the same rate. The vibrations of the first fork and of the box on which it is mounted set up waves in the air. The waves set the second fork and box into vibration. Just as a series of slight pushes, if delivered at the right time, will start a person moving on a swing, so the small force of a sound wave will move the heavy fork and box. The vibration of the boxes causes the sounds to be louder and more prolonged. Such an effect is called resonance.

Another standard demonstration of the effect of sound on the air is performed by placing an alarm clock, set at "repeat," on a rubber pad under a bell jar. When the air is pumped out, the ringing becomes fainter and fainter. When the air is admitted again, the bell can be heard ringing as loudly as ever.

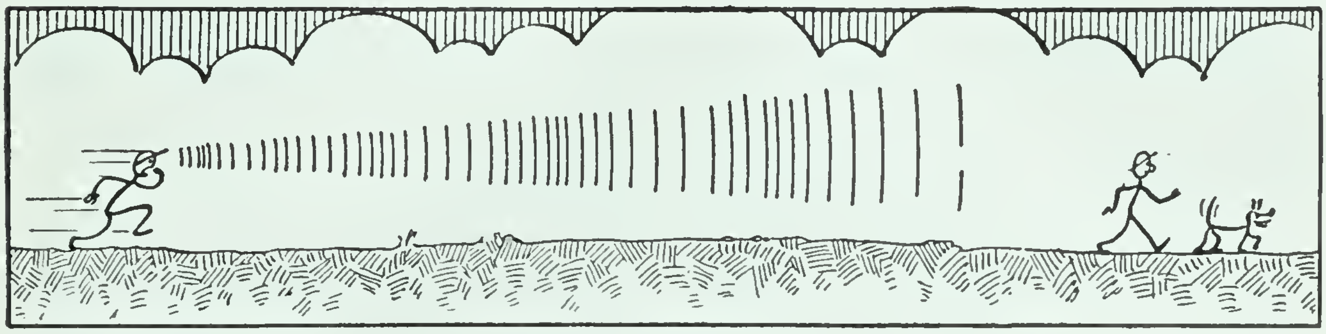
What are echoes? When a sound wave strikes a solid object, its energy may be absorbed and changed to heat or the object may be caused to vibrate or the wave may be reflected. The reflection of sound is called an echo. Echoes out of doors are usually caused by reflection of sound from a cliff or an earth bank.

Echoes indoors are usually annoying. They may travel back and forth across an auditorium for a second or two, making enough noise to interfere seriously with the sound of the speaker's voice. Echoes in recording and broadcasting stations cause sounds to be changed and distorted in tone. To avoid these echoes, walls are usually covered with drapes or curtains or made of porous wallboard. Ceilings are also covered with wallboard. Floors are either covered with rugs or made of linoleum laid on felt.

What determines loudness of sound? The loudness of a sound depends upon the force used to produce it. Loudness is measured by an electrical device which produces a current in proportion to the sound. The unit of measurement is the decibel. One decibel is the faintest sound audible to human ears, while a sound of 130 decibels is so loud as to be painful and injurious to the ears. The sound of wind over the grass is one of the least loud sounds people notice. City traffic



Sound travels at the rate of about 1100 feet per second. For accurate timing of races, it is necessary to start the watch by the flash instead of by the sound of the gun.



Sound waves are not powerful. Their energy is changed to heat and lost. The boy calling cannot set up waves strong enough to reach the second boy.

noise is from 60 to 80 decibels. Most traffic noise is avoidable, and we should not tolerate it.

School noises vary greatly in loudness. The noise of breathing, turning pages, and slight movements in an otherwise quiet classroom may be not much more than 20 decibels. A lively discussion may bring the level of loudness up to 40 or 50 decibels. At passing of classes, hall noises may be as much as 60 decibels, but disorder, shouting, and whistling may bring it up to 80 or 90 decibels.

Although people do not do their best work in absolute quiet, neither do they do good work in too much noise. A noise level above 50 decibels is considered harmful. Nervous strain, muscular fatigue, increased tendency to make errors, and loss of attention result from noisy surroundings. Classes should be conducted on a noise level so low that ordinary conversation is easily heard. You should not have the radio on when you study at home.

What is the speed of sound? Sound travels under ordinary conditions at the rather slow speed of 1090 feet per second. Many guns shoot bullets which travel faster than the sound

of the shot. One can tell how far he is from a shot or a flash of lightning by starting to count seconds when he sees the flash and allowing about five seconds for each mile. If seven seconds pass between the flash of lightning and the thunder, how far away is the lightning?

Sound travels about four times as fast in water as in air and about 14 times as fast in steel as in air.

Why do people sometimes need hearing aids? Even for people with normal hearing, there are many sounds too faint to hear. If an injury to the ear occurs, loss of hearing results. Usually loss starts with inability to hear high tones, those which have a frequency of 10,000 to 20,000 a second. The hearing loss may become more complete with time, until not even loud, low-pitched sounds are heard.

Injury of any part of the ear may impair hearing. If the eardrum is broken by a blow or by a sharp instrument, the sound wave encounters nothing against which it can act. Infection may destroy any part of the ear—the drum, the bones, the inner drum, or the cochlea. In the cochlea the nerve endings which respond to sound waves lie in a liquid. The cochlea is snail-shaped, and it is divided lengthwise into three divisions. The nerves lie along the dividing wall, those nearest the outer end detecting the highest-pitched sounds. If the passages of the ear become closed by growth of adenoid tissue or by infection or by pressure of the jaw muscles, hearing may be impaired. Professional swimmers and divers are very likely to suffer impaired hearing. Why?

The most common hearing aid is much like a radio. There is a microphone which picks up sound waves, an electrical device which makes them louder, and an earphone which carries the sound to the ear. If part of the ear has been destroyed, the sound may be conducted through the bones of the head instead of through the ear. To accomplish this bone conduction, the receiver is clamped against the head just behind the ear. The type of hearing aid needed depends upon the cause of the loss of hearing.

Demonstration. What Is Sound?

What to use: Tuning fork, cigar box, tuned forks or bars, pith-ball electroscope.

What to do: Tap the tuning fork. Pass it around the class. Hold the vibrating fork against the pith balls. Hold the handle of the sounding tuning fork against the bottom of an inverted cigar box.

Do the experiment with the tuned bars or forks as described in the text. Do any of the other experiments described in the text for which equipment is available.

What was observed: Describe briefly what happened.

What was learned: How is sound produced? How does it travel?

Exercise. *Complete the following sentences:* A tuning fork sets up —1— which produce —2— which travel through the air. Sound could not reach us from outer space because it does not travel through a —3—. Reflected sounds are —4—. Sound which is absorbed is changed to —5—. Sound travels —6— feet per second or one mile in about —7— seconds. The nerves of hearing lie in the —8— to which sound is transmitted from the —9— by the three —10—. The unit of loudness of sound is the —11—.

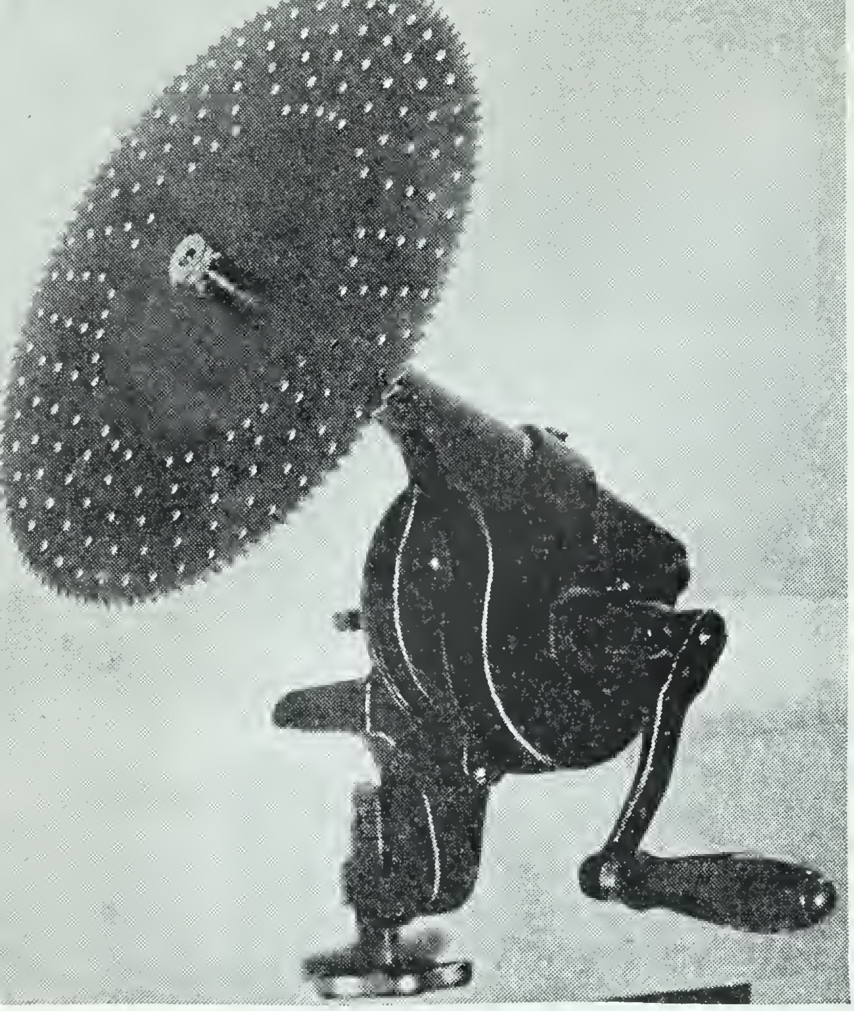
Science activity. Make tin-can telephones. Connect two cans with 40 feet of waxed string, stretched tight and tied through holes in the bottoms of the cans. Speak into one can while someone uses the other can for a receiver. Does sound travel through solids?

2. Why do sounds sound different?

You have observed, unless you are deaf to tones, that some sounds are high pitched, while others are low pitched. Some sounds are pleasant, others are unpleasant. Do you know why?

What is pitch? Pitch is the highness or lowness of a sound. It is determined by the number of vibrations made per second by a sounding body. The most accurate measurement of pitch is made by complex, electrically operated devices.

Have you wondered how a siren produces its sound? The siren disk is made of metal and notched on the rim. A strip of metal is held against the notches as the disk rotates. The faster the wheel is rotated, the shriller becomes the sound. The familiar siren effect is produced by varying the speed of the disk. We can also use a disk in which regularly spaced holes are punched to produce the major chord—the do-mi-



The siren disk is rotated at varying speeds. A stiff card is held against the holes or the notched edge to produce sound. In fire sirens a blast of air is blown through the holes to produce sound.

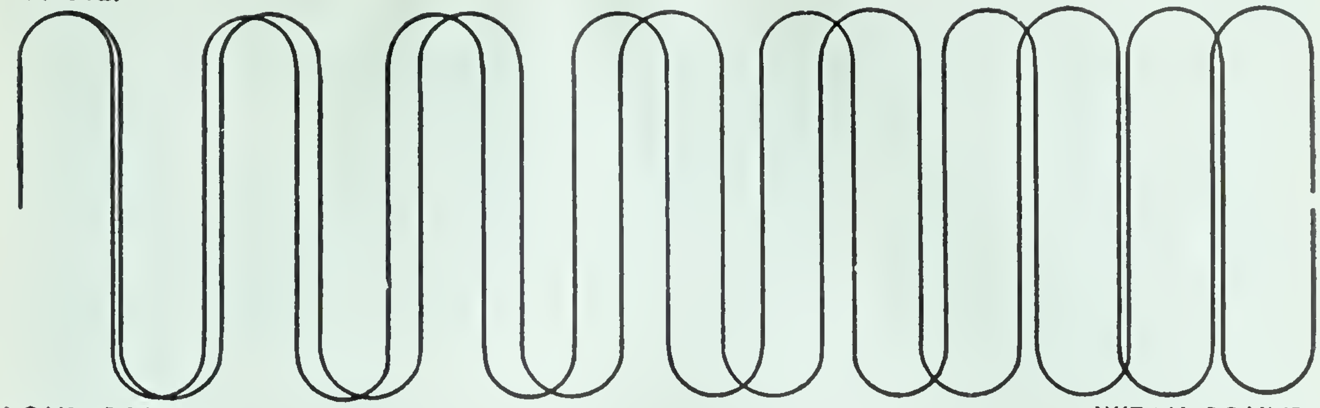
sol-do you learn in singing. By counting the number of holes in the disk, we discover that there is a definite relation between one tone and another.

There are two systems of figuring pitch. One is the musician's scale, which is based upon an *A* of 440 vibrations per second; the other is the scientist's scale, based upon a middle *C* of 256 vibrations per second. Practically, the difference in scales is slight, but any device in tune on one system would be out-of-tune with instruments tuned with the other. The musician's middle *C* is slightly higher than the scientist's middle *C*, being not quite eight vibrations per second more.

What is music? There are various ways of defining music, but probably the most accurate is to describe it as tones which are caused by vibration at regular intervals in combinations which have a certain mathematical relation to each other.

A series of holes punched at regular intervals in a uniformly rotating disk produce a musical tone, while a series of holes punched at irregular intervals produce a rasping noise. The regularity and harmony of vibration is basic to music. The fact that some popular music violates this principle accounts for its short life.

When two vibrating bars are placed together, almost in tune, the sound alternately increases and fades in volume. If the bars are tuned at an interval of two vibrations per second apart, there are two loud and two weak sounds per second. The waves of the sound, when they are out-of-step, push on the air molecules in opposite ways, and the sound is diminished as the molecules stand still. When the two



Sound waves may make each other stronger, or they may interfere with each other. Waves "in step" add their energy together, while waves "out of step" oppose each other.

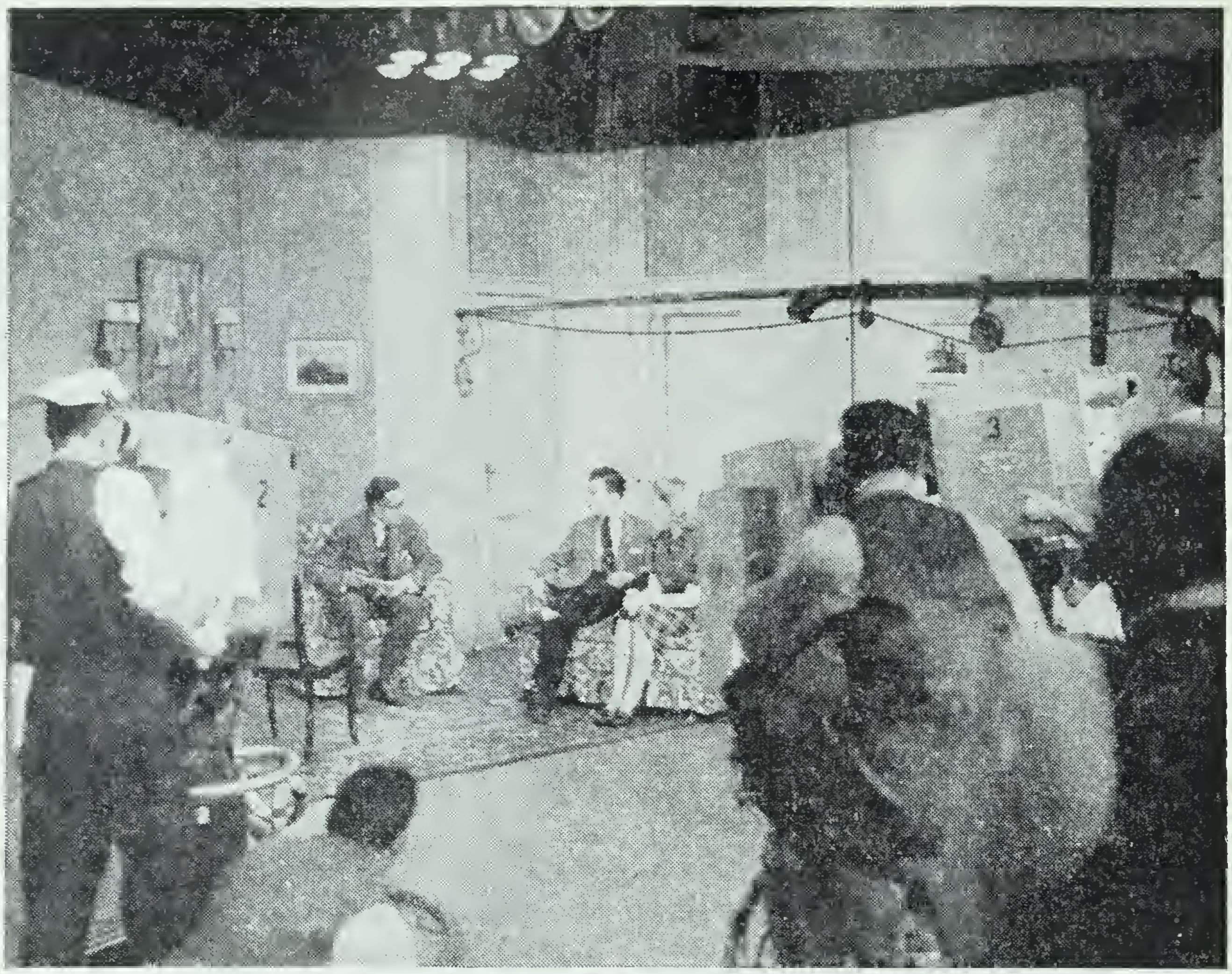
waves are in step, both push the molecules in the same direction, increasing the loudness of the sounds. Thus you see that one sound can offset another, and the combined effect of two sound waves is silence.

What determines pitch? When we wish to produce sounds of different pitch on the piano, we strike different keys. The keys cause hammers to strike wires inside the piano. If we look at the action of the piano and observe what wires are struck, we learn that the shorter, thinner wires produce the higher-pitched tones, while the longer, thicker wires produce the lower-pitched tones. To produce tones of different pitch on a violin or guitar, we move our fingers to change the length of the strings.

To tune a stringed instrument, we tighten or loosen the strings. If we tighten a string, we make it higher pitched; but if we loosen the string, we lower the pitch.

The pitch of the tone of a horn is produced in part by the vibration of the lips or the reed and in part by the length of the tube through which the sound passes. Xylophone [zī′lȯ·fōn] bars are tuned in the same way that strings are, the longer bars having the lower tones. The lowest-pitched pipes of a pipe organ are large enough to use for culverts, while the smallest, highest-pitched pipes are the size of a lead pencil.

In addition to the fundamental tone, other tones are sometimes produced by the vibrating body. If a string vibrates as a whole, it may also vibrate to a smaller extent in two



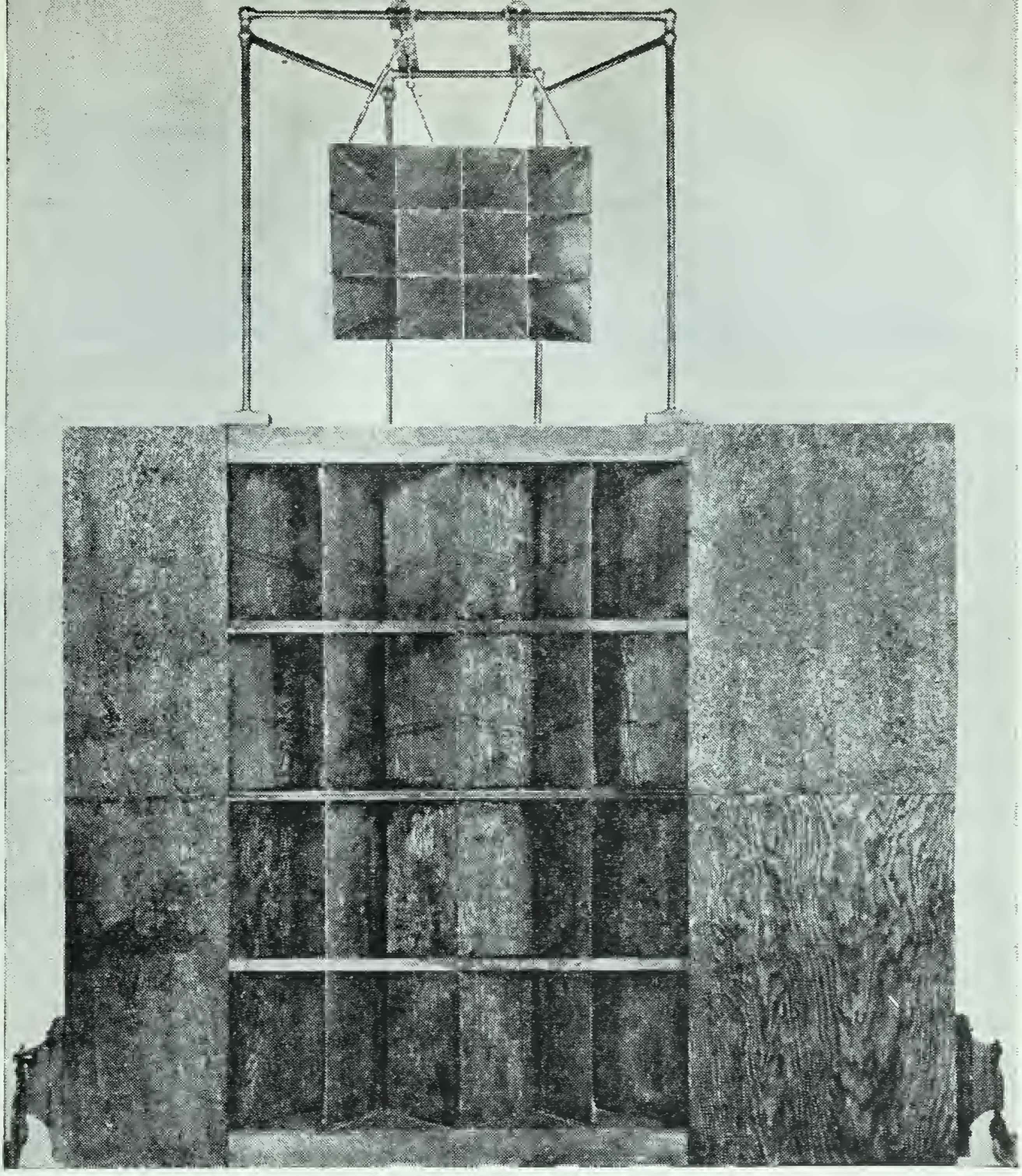
Courtesy National Broadcasting Company

In this television studio sound waves travel from the people to the microphone hanging on the long arm, or boom. Three television cameras are in use. Both sound and pictures are broadcast.

parts, producing two tones at one time. These overtones give music much of its pleasing quality. A tuning fork produces a purer tone than does a violin, but the tone is less pleasing.

High-frequency sound waves have some unusual uses. Milk which has been treated with sound waves of high frequency forms smaller curds than does ordinary milk. Sound waves have been used experimentally to cause smoke to settle in chimneys. A glass tube may be vibrated so rapidly by sound waves that if the skin touches it, a burn appears, although the tube is cold.

What are the various types of musical instruments? The types of musical instruments commonly used in the orchestra and band are of three classes: percussion [pẽr·kŭsh′ŭn], stringed, and wind. The word "percussion" refers to striking. Drums, bells, triangles, cymbals, and related instruments



Courtesy Western Electric Company

This two-way sound motion picture loud-speaker can produce sounds ranging from 30 vibrations per second to more than 10,000 vibrations per second. The lower part produces the bass notes, the upper part the higher pitched tones.

are played by striking. Each of these instruments usually produces only one tone. They are used for producing rhythm. The xylophone and other instruments made of tuned bars are used for playing a tune.

The stringed instruments are the violin, guitar, cello, piano, and other related instruments. These are played by striking, picking, or bowing the strings to set them into vibration. The musical saw must be considered to be a string of unusual shape. Stringed instruments consist of a sounding box

This device is used in the experiment to produce sounds of different pitch by comparing strings of varying sizes, tightnesses, and lengths.

in which air columns are echoed to give resonance [rĕz′ ō·năns, a resounding] and tone quality to the tones of the strings. If you wish to see the difference produced by the sound box, attach a violin string on a broomstick with screw eyes, and support the string on a bridge. Ask someone to play a tune on it, and note the strange, thin tone.

The wind instruments are either the brass winds or wood winds. The trumpet, French horn, and trombone are brass instruments. The clarinet, flute, and bassoon are wood-wind instruments. In playing the horns, such as trumpets or trombones, the lips are vibrated by blowing as if you wish to blow a feather from your lip. The reed instruments, like the clarinet, are played by causing a wooden reed to vibrate by blowing into the mouthpiece.

Demonstration. How Are Musical Tones Produced?

What to use: Wire string, sonometer *or* board with screw eyes *or* board, C-clamps, Stone tension clamp, spring balance—to 24 pounds, adjustable tuning fork.

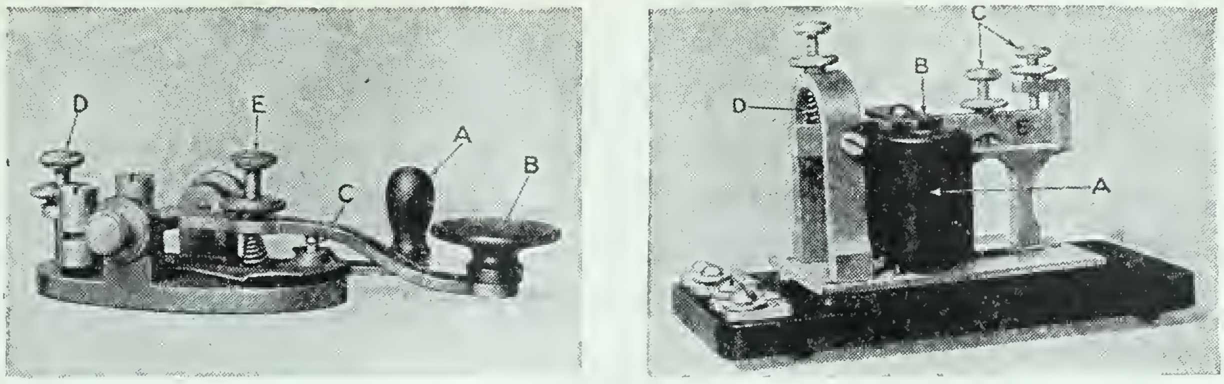
What to do: How you do this demonstration depends upon the equipment available. The drawing shows how the clamps are used with the spring balance. Tighten the string, and place the bridges as shown. Pluck the string. Move the bridges closer together, and again pluck the string. Repeat several times. Then change the tightness of the string. Compare the various combinations.

Sound the adjustable tuning fork; make the sound audible in the room by holding the fork on a cigar box, and then repeat after adjusting the fork to produce another tone.

What was observed: Sketch the apparatus you used. Establish three rules which determine the pitch of a string.

What was learned: How are musical tones of differing pitch produced?

Exercise. *Complete the following sentences:* A musical tone is pleasing because the vibrations are at —1— intervals. The scien-



The parts indicated on the telegraph key, to the left, are the switch (A), the lever (B), contacts (C), and setscrews (D and E). On the telegraph sounder *(right)*, A is the coil; B is the armature; C indicates the setscrew; D, the spring; and E, the sounder bar.

tific scale is based upon a middle C of —2— vibrations per second, the musical scale upon an A of —3— vibrations per second. The smallest number of vibrations that can be heard is —4— per second, the largest number —5—. The pitch of any object is determined by the number of —6— per second. Tones of strings may be changed by changing the —7— or —8— or by using strings of differing —9—. The drum is a —10— instrument, the trumpet a —11— instrument, and the violin a —12— instrument.

3. How do we communicate by telegraph?

The telegraph is not used directly by as many people as are the telephone or radio, yet indirectly it affects our lives in many ways. The telegraph plays a very important part in issuing daily newspapers, both in sending messages for stories and for sending pictures. It is necessary for operation of railroad trains. The businessman uses the telegraph when he wishes to have an order filled quickly. It is possible to use the telegraph to have a stenographer in one city type out letters that may be read immediately in another city.

Although there were telegraph instruments before 1844, the successful magnetic telegraph was patented by Samuel Morse in that year. A British system had been in use for some time before this date, but it is operated on a different principle.

The first commercial line extended from Washington to Baltimore. At present there are about a quarter of a million miles of line and nearly two million miles of wire in use. The first Atlantic cable was laid in 1857. Now cables cross

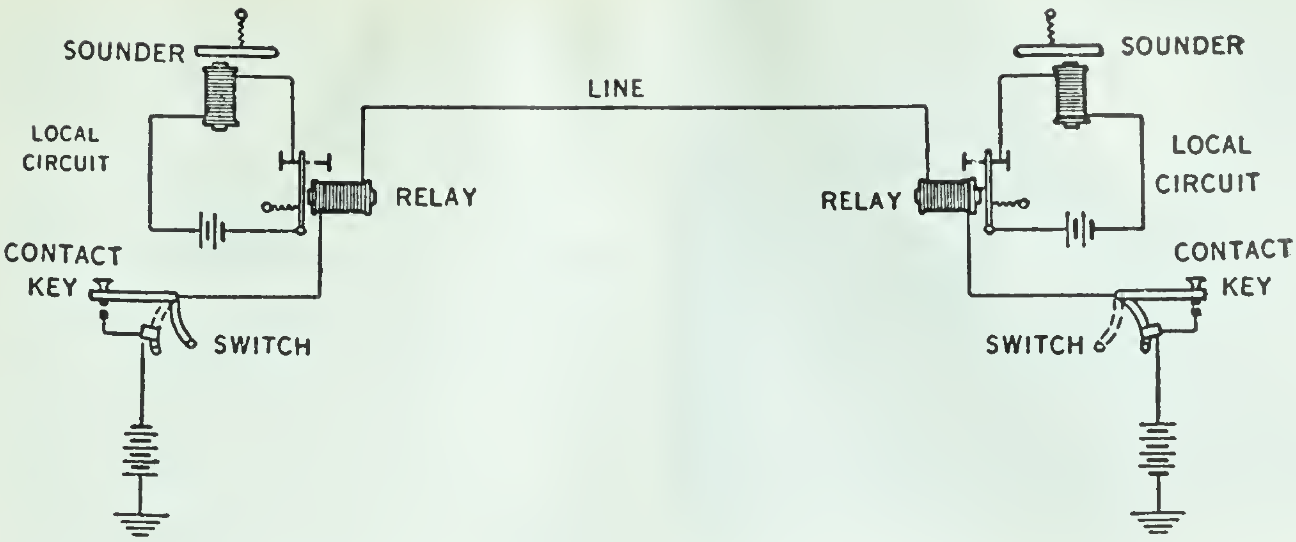
every ocean. The average person in the United States receives more than two telegrams a year.

How does the telegraph work? In its simplest form, the telegraph consists of three parts: the key, the sounder, and a battery with connecting wires. The connection between towns is a single wire, the return current necessary to make a complete circuit being carried by the ground. To make a ground connection, a piece of metal is sunk deep into the earth in contact with moist soil.

The sender is really a simple electric switch which is used to open and close a circuit. It is similar to a push button or knife switch. The kind of key shown on page 599 is the simplest and easiest to understand. However, it causes a jolt when pressed down, and to avoid this jolt the commercial key is made to be pushed sidewise. The second part of the sender is the switch. When the operator wishes to send a message, he opens the switch; when he has finished, he closes the switch. When the switch of the receiving set is closed, the only break in the circuit is at the sending station, and it may be closed by pressing down on the key. If the switch is open at the receiving station, it is impossible to make a complete circuit.

The receiver, or sounder, as the name suggests, is the instrument by means of which sounds used in sending messages are made. It consists of an electromagnet with an iron armature across its poles. When the key is closed and a current passes through the sounder, the electromagnet pulls down the armature. The armature strikes against a piece of metal, making a sharp click. When the connection is broken at the key, the electromagnet ceases to hold the armature, which is then pulled back by a spring to which it is attached. When the armature flies back, it strikes a second piece of metal, making another click. These two clicks make up the dot, if the interval between is short, or the dash, if the interval is long.

Why is code used? For each letter of the alphabet, a code of dots and dashes has been arranged. There are two codes: the Morse and the International. The latter is more widely used. The letter A is represented by a dot and a dash, thus: ·—. The letter G is represented by ——·. Expert



The current flowing through a telegraph line is not strong enough to operate a sounder. Instead, the current is used to operate a sensitive switch called a relay which, in turn, operates a second circuit of which the sounder electromagnet is a part.

telegraphers learn to read these signals by ear. The code is also printed on paper by a roller wheel over which a strip of paper passes. The wheel is pressed against the paper when current is flowing. The wheel dips in ink and prints dots and dashes on paper.

Only a small percentage of messages are sent by code today. Sports-writers sometimes carry portable sets and send by code, and code is used in smaller stations and towns for railroad business. The code, made by a buzzer, is widely used by radio amateurs.

What is a relay? The simple telegraph just described will not work for long distances because the current is not strong enough to operate the sounder. The relay uses a weak current from the main line to control a stronger current which operates the telegraph set. The relay is really a very lightweight switch operated by an electromagnet. It consists of an electromagnet and an armature. When a current flows through the main line, it opens the circuit of the local sounder by attracting the armature of the relay through use of magnetism. When the main-line current stops, the local circuit is closed again, producing the second click. The relay has four binding posts, two of which connect with the main line and two with the local circuit. The diagram at the top of this page shows how the connections are made.

Why is a closed circuit used? The telegraph system is operated on a closed circuit, because the wet cell loses its

Courtesy Western Union Telegraph Co.

Telegrams are transmitted over long distances by the multiplex system, which permits sending eight telegrams over a wire at one time. The operator above is sending a message by multiplex. A telegram is received on the multiplex system on a paper tape and pasted on the telegram blank as shown below.

Courtesy Western Union Telegraph Co.

strength unless it is producing a current. Dry cells are not used in telegraphy.

What is multiplex telegraphy? The use of a wire for a single message at a time is extremely wasteful. Systems were early devised to send two messages over the same wire at a time, and at present a large number of messages may be sent at one time. The machinery of multiplex systems is complex, but it operates on a principle you can understand.

You know that one tuning fork will cause another of the same rate of vibration to be set in motion. Similarly, electric currents may be used to set a second object into vibration in tune with the first. Pairs of sending and receiving devices are so tuned that only one current frequency will cause them to work together. Several currents of different frequency may pass over a wire at the same time and be separated out by the devices which receive the message.

What are the teletype and automatic printing devices? In most of the large telegraph offices of the United States, the message is typed on a typewriter keyboard, and the message comes out at the

other end of the wire from another typewriter, typed upon a strip of paper. The strip of paper is pasted upon a telegraph form, and the telegram is ready.

It is possible to set type by telegraph. A single linotype (a typesetting machine) operator can set the type for any number of newspapers. This is done only on certain material that is desired in all cities, for local news that is interesting in one city might have little appeal in another. For stories of national importance the device permits saving of time.

The most important work of telegraphy is to carry messages quickly and to permit transmitting printed or typed material just as it is written. There are devices by which even handwriting may be sent by telegraph, making it possible for a document requiring a signature to be sent by wire.

Demonstration. How Does the Telegraph Work?

What to use: Simple demonstration telegraph set, wire, and cells.

What to do: Set up keys and two sounders, and practice sending code. Observe how the instruments are adjusted to make two clicks. Study the wiring until you can draw a diagram of it.

What was observed: Diagram the wiring of the key, cell, and sounder.

What was learned: On what principle of electricity does the telegraph instrument depend?

Filmstrip: Telegraph. S.V.E.

Exercise. *Complete the following sentences:* When the telegraph —1— is pressed down, a circuit is completed, and current flowing through an —2— attracts an iron —3—, causing a click. When the key is released, the coils lose their —4—, and a —5— pulls back the armature, causing a second click. A short time between clicks represents a —6—, a longer time a —7—. To make possible use of a weak main-line current, a —8— is used. Telegraph circuits are kept —9—.

Science activity. Make a model telegraph system. Use a door hinge for the armature. Wind a nail to make an electromagnet. Fasten it above the hinge. Below the hinge place another nail, where the free part of the hinge can rest on it. Make a key from a strip of metal and a nail. Before you actually make the telegraph set, work out a method of supporting the hinge, the nails, and of connecting the wires.

Northwestern Bell Telephone Co.

The dial telephone is a convenience in that it makes each person responsible for making his own call. The dials automatically select the correct connection and cause the bell to ring.

4. How does the telephone aid communication?

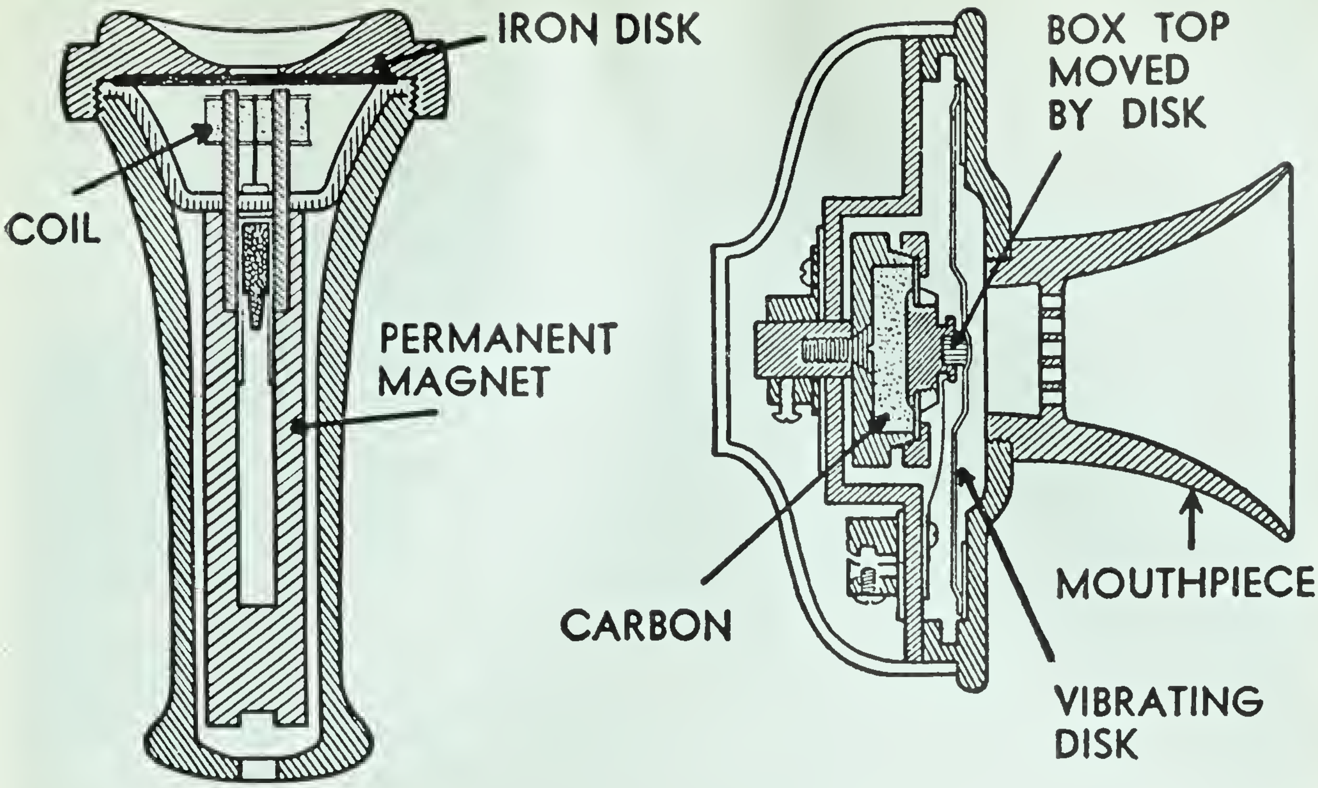
Of all the inventions of the last century, few have become more a part of the everyday life of the people of the United States than has the telephone. More than half the telephones in the world are in the United States.

The telephone was invented in 1876, more or less accidentally, by Alexander Graham Bell while he was working on a telegraph set that would carry music. The first public telephone was installed in 1877 in Massachusetts. By the end of the first year 776 telephones were in use. Today the use of the telephone is so extensive that one can talk by telephone to almost any person in the United States or in any large city in the world. There are now about 20 million telephones in the United States—or about as many as there are automobiles.

It is estimated that there are about 72 million telephone conversations a day. To connect these telephones, more than 70 million miles of wire are used.

What do telephone wires carry? Since you seem to hear voices over the telephone, you might imagine that the wires carry sound waves. Such is not the case. Because of the low speed of sound, it could not travel long distances fast enough to make conversation possible. To talk to a friend 10 miles away, you would have to wait 50 seconds for the sound waves to reach you and then wait 50 more seconds until your voice reached the other person. The telephone wires carry electricity, which travels with slightly less speed than does light. What you hear is the vibration of a piece of metal in the receiver.

What does the transmitter do? The sender of the telephone is called a transmitter. Its parts are the mouthpiece, which



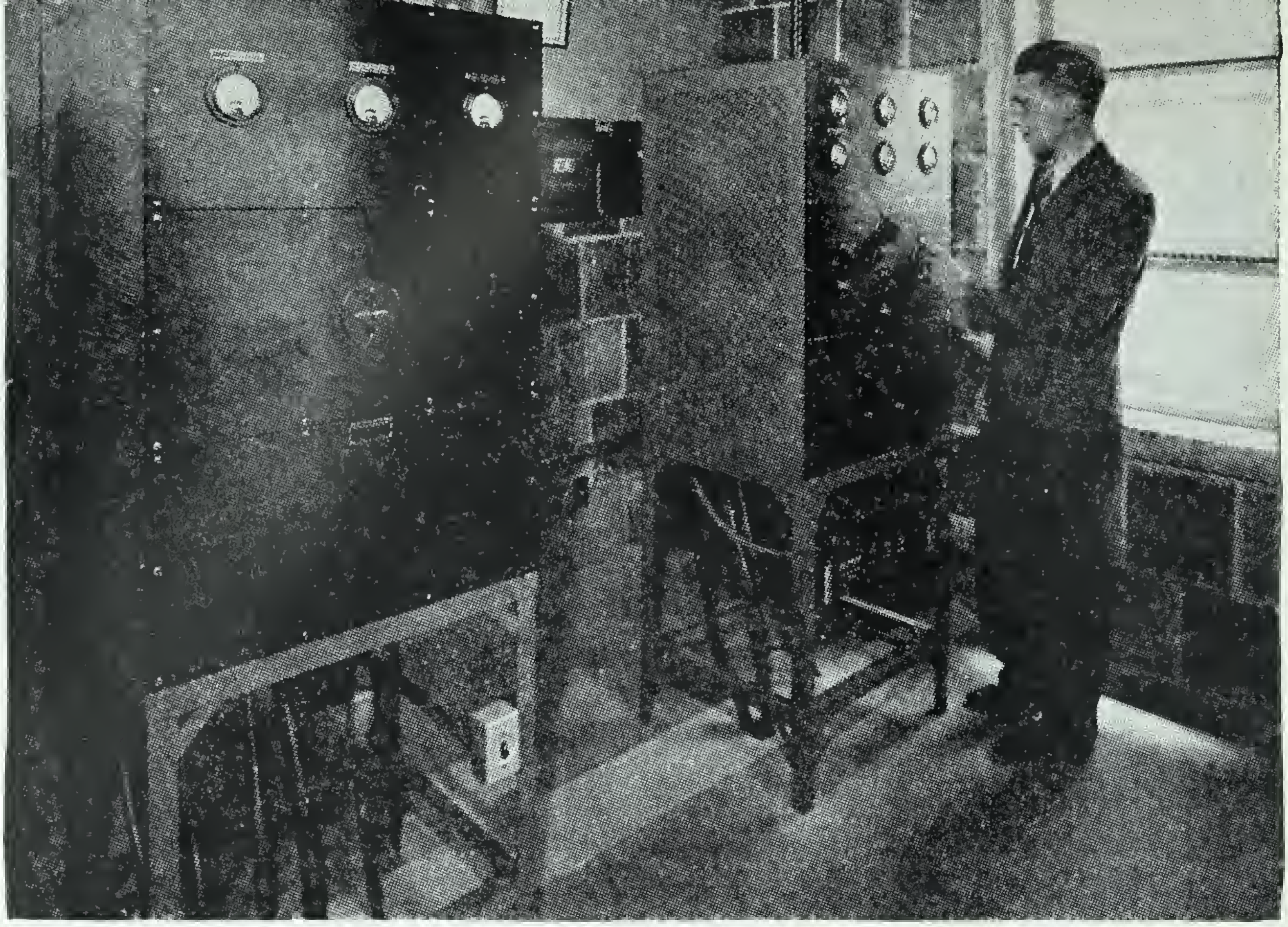
The telephone receiver and transmitter are comparatively simple devices. One depends upon an electromagnet to vibrate an iron disk. The other depends upon a vibrating disk to control the strength of a current.

collects and concentrates sound waves; the disk, which is vibrated by sound waves; and the carbon particles in a small box. Connections are provided so that the current flows through the box.

When you speak into the transmitter, the sound waves set up by your voice cause the disk to vibrate. The disk is attached to the cover of the small box shown in the diagram, and the cover is moved back and forth in step with the sound waves. The cover of the box has no direct electrical connection with the box itself. The only way that current can flow through the box is by passing through the carbon grains. Current is carried through the box by wires attached to batteries.

As the cover of the box moves inward, the carbon particles are moved closer together. When they are close together, the resistance is decreased and there is a larger current. When the air waves permit the cover to move outward, the particles are farther apart and there is less current flowing through the box.

The object of the transmitter, then, is to change the strength of the current in proportion to the frequency and strength

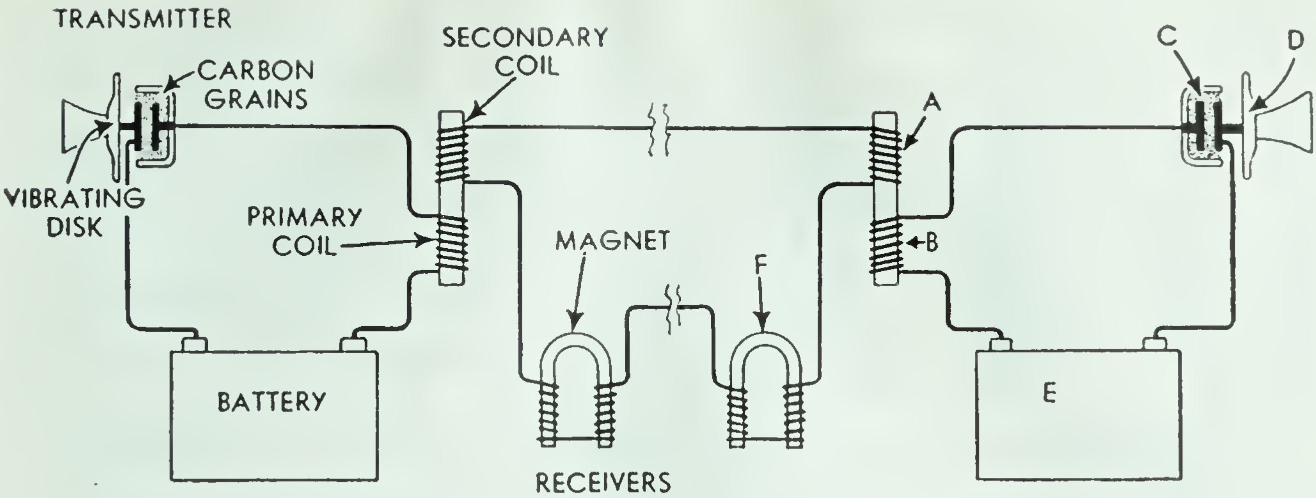


Courtesy Western Electric Company

This station receives radio messages from boats and connects to the regular telephone system. The rectifier at the left provides power. The station is completely automatic in making connections and shutting off the current.

of the sound waves. The transmitter is a form of the rheostat, a device for changing resistance.

What does the receiver do? The receiver reproduces the sound waves that enter the transmitter. It consists of a permanent U-shaped magnet, with a coil or wire wound around each end to make an electromagnet. In front of the magnet is a soft iron disk, called a diaphragm. When the varying currents set up in the transmitter reach the receiver, they produce varying currents in the coils of the electromagnets. When a strong current passes through the wires, the electromagnet pulls the diaphragm through a greater distance than when a weaker current passes through. Thus the diaphragm of the receiver is made to vibrate by the electromagnet at exactly the same rate that the transmitter diaphragm is vibrated by the voice. The vibrations of the diaphragm set the air in motion inside the receiver, producing sound waves. Each telephone has a transmitter and receiver, which we use alternately. The first telephones combined the two. It is possible to wire telephone receivers in such a way that for short distances they may be used as transmitters.



This diagram shows the essential parts of a complete telephone system. With the help of the text, trace energy from the sound waves striking the vibrating disk through to the receivers. Match the letters on one half the drawing with the words on the other half.

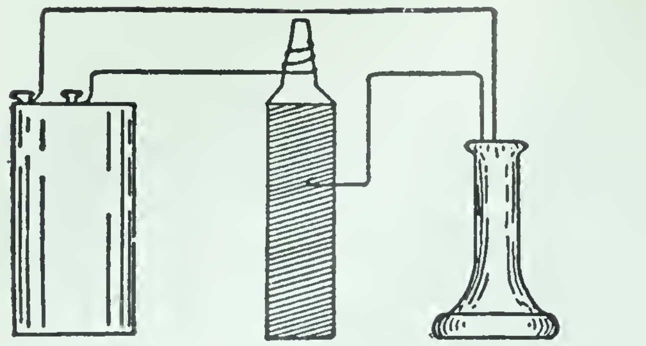
How do currents cover long distances? We know that sound does not travel far. The electric current that we study in the laboratory soon loses its strength when it encounters resistance in wires, and the current does not travel far, either.

There are several ways of making currents travel long distances. One is by the use of the induction coil. Instead of the current from the transmitter being carried through the wires directly, it is first sent through the primary coil of an induction coil. An induced current of much higher voltage travels over the wire, and as a result less of the current is lost as heat energy.

A second way of increasing the strength of currents is to use radio tubes as relays. The working of this type of amplifier will be explained when we study the radio. A very weak current entering the tube is used to control a much stronger current in another circuit. These amplifiers are used in all long-distance communication.

What does Central do? Each telephone in a system may be connected to any other telephone by connections made at the central telephone exchange. The wires from each telephone end in a plug connection. To connect any two lines, a cord is plugged into each of the connections, completing the circuit. The cords are handled by Central.

In most large-city systems, the Central is completely automatic. The series of numbers is dialed by turning a disk in which holes are cut. To dial 9, the disk turns more than half



a revolution; to dial 2, the disk turns a short distance. The dial clicks a connection which operates a complex series of electromagnets. These electromagnets in the central exchange make the desired connection. From this you can see that the dial system is extremely complex in its operation.

DEMONSTRATION. HOW ARE SOUND WAVES PRODUCED BY TELEPHONES?

What to use: Telephone receiver, wires, dry cell, file, induction coil.

What to do: Connect the apparatus as shown in the diagram. Draw the loose connection across the file, listening to the sound in the receiver.

Connect the cell to the primary of the induction coil and the telephone receiver to the secondary.

What was observed: Describe the sounds caused by each of the parts of the demonstration.

What was learned: How do you know that sound can be produced by electric currents?

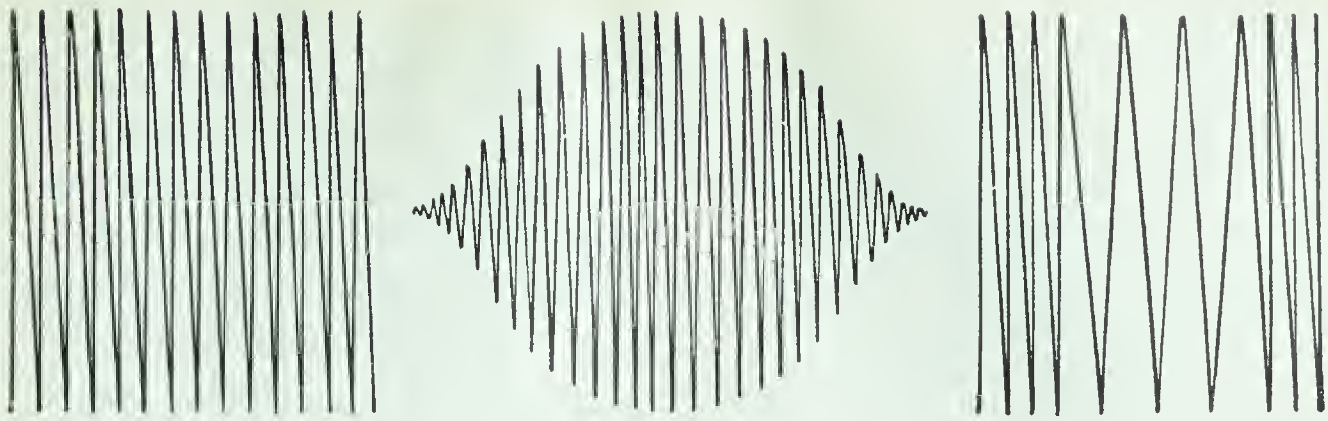
Filmstrips: Telephone—Central Station: S.V.E.
Telephone—Outside. S.V.E.

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* transmitter, carbon grains, resistance, metal disk, sound waves, electromagnet, varying current, vibrate, conducts electricity, permanent magnet, soft iron.

Science activity. Arrange to visit an up-to-date telephone exchange in a large city.

5. How are radio messages sent?

You may at first wonder why you should need to know any more about radio than how to turn the dial and turn on the current. For some, this is enough. But the average person wants to know, at least as far as general principles are concerned, how common devices work. Then too, many boys and girls become amateur radio operators. Any boy or girl who wishes to make his own radio may listen to short-wave tele-



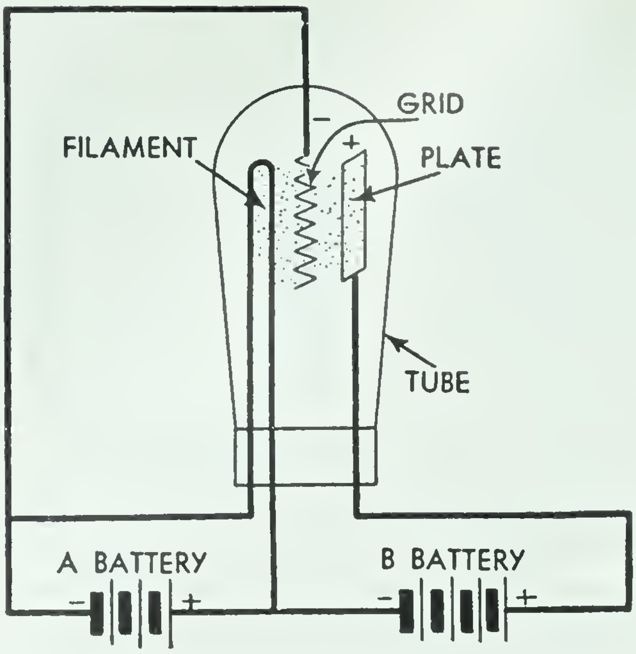
The generated wave is a powerful alternating current. It does not vary in strength, nor does the interval between waves vary. A wave may be modulated, or changed, in strength as in amplitude modulation; or the interval between alternations of the current may vary as in frequency modulation.

graph signals in code and to conversation. If you want to own a sending station, you must pass a test and obtain a license from the United States Government.

Radio is so important commercially that millions of radiograms are handled between shore and ship. All regularly scheduled airlines are controlled by radio. About a third of the Atlantic and a half of the Pacific transoceanic telephone and telegraph messages are handled by radio. Much of the information of the Weather Bureau is collected by automatic radio devices. Even if commercial broadcasting for entertainment were stopped completely, radio would still be important. But today most families have a radio of some sort. On some farms and in remote forest stations and camps radio is the only contact with the world.

What are radio waves? Radio is applied electricity. You know that a current in a primary coil sets up a magnetic field that cuts through a secondary coil, setting up a voltage in the secondary. Radio waves are magnetic in nature. Just as magnetic waves may travel through space from one coil to another, radio waves may travel through space from one aerial to another. Radio waves have a greater frequency—that is, there are more of them per second—than the magnetic waves of the primary coil of a transformer or induction coil.

Radio waves are part of the radiant energy group and are the longest radiant waves. They are next to infrared waves



This diagram shows the parts of the radio tube, and how they are connected to batteries. The dots represent a flow of electrons from the filament to the plate.

in length and much longer than light waves. Radio waves travel through space in straight lines and may be reflected by the earth and by the electrically charged upper air. There is a layer of charged air several miles above the earth which reflects radio waves and keeps them from being lost in space, in somewhat the same way in which light is reflected from a mirror.

Radio waves travel at the same speed as light waves, 300,000 kilometers per second. Because radio is worked out by scientists, all measurement of waves is done in the metric system. If the wave length is 300 meters (about 1000 feet), the frequency is 1000 kilocycles, or one million complete changes per second. This wave length and frequency are typical of ordinary broadcast waves. Short waves have higher frequencies.

Sound waves are slow. Only 100 to 3000 vocal sound waves pass a given point per second. An important problem in broadcasting is to so combine the slow sound waves with the fast radio waves that the radio waves carry sound. If 250 sound waves pass a point at the same time that a million radio waves pass the same point, it is necessary for each sound wave to be carried by 4000 radio waves. $(1{,}000{,}000 \div 250 = 4000)$.

What does the radio tube do? Radio tubes do three things. They set up magnetic waves having the same frequency as the sound waves. They change alternating to direct current. They make possible the control of a large current with a small current. To understand how they do this, we must learn the parts of a radio tube.

The central part of the radio tube is a hot *filament,* like the one in the ordinary electric light bulb. On one side, or surrounding the filament, is a metal *plate.* Between the filament

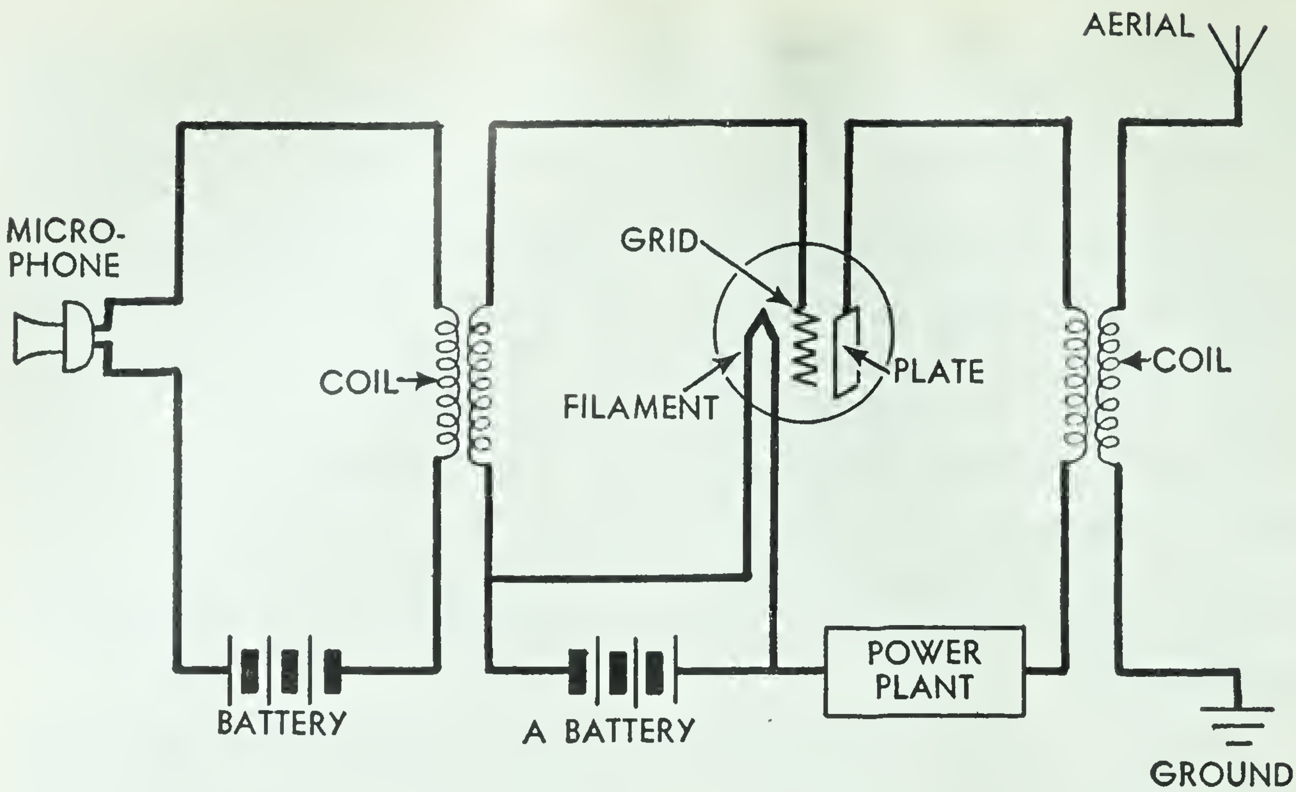
and plate there is a screen, called a grid. The filament is kept hot, just as a lamp filament is, by a current passing through it. The plate is charged with a positive charge, by being attached to a battery or a source of current.

You know that electrons are charges of negative electricity and that a current is a flow of electrons. Now, if we could get the electrons to flow from the filament to the plate, we would have a current through the space in the tube. A hot filament does give off electrons, and the electrons, being negative charges, are attracted to the positively charged plate because unlike charges attract. This current is of no use for making radio waves, however, for it is even and unchanging in strength.

The grid is between the filament and plate and connected to the negative side of the circuit. Consequently, its charge is always negative. If it were positive, it would collect all the electrons and keep them from flowing to the plate. The strength of this negative charge varies. When it is strongly negative, it repels the electrons to such an extent that they return to the filament. When the grid charge is weakly negative, it repels the electrons enough to prevent them from sticking to the wires of the screen as they slip through the spaces to the plate. The grid serves as a gate or valve to control the flow of electrons.

The strength of the negative charge is controlled by an induction coil. When the charge in the coil tends to make the grid positive, the positive charge from the coil offsets some of the negative charge of the grid. When the charge from the coil is negative, it strengthens the negative charge of the grid. The grid, then, strengthens or weakens the current through the tube.

How are sound waves combined with radio waves? You know that a telephone transmitter sets up currents of varying strength, which pass through an induction coil. If we attach the secondary coil to the grid of a radio tube instead of to a telephone wire, we can change the strength of the negative charge every time the current strength of the transmitter is changed. The changes in the charge of the grid are fairly slow, so that the radio waves are changed in strength, as shown in the diagram on page 609.



The radio transmitter is much more complex than this simple diagram, which shows only the essential steps in changing sound waves to radio waves. Study the diagram with the aid of the text.

What is the hookup of a transmitting set? There are so many parts to a radio sending station, and they are so complexly connected, that we shall go over only a few of the steps, which give you a general idea of the whole process.

The filament is kept hot by one circuit, which is called the A battery circuit, although batteries are no longer used. The current which flows from the filament is provided by the B battery circuit. The grid is connected to the negative post of the B battery circuit, which is replaced in the diagram above by the power plant.

The coil from the telephone transmitter is connected to, or to a part of, the grid circuit. The telephone controls the grid charge.

The current flowing from the filament to the plate in the B circuit flows through the primary coil of the aerial circuit. The aerial is attached to the secondary part of this coil, and a current flows back and forth from the ground to the aerial in the secondary when the strength of the current changes in the primary.

There are many parts, such as coils, condensers, grid leaks, power tubes, and rheostats, necessary to complete the operation of the transmitting set. Including them in the diagram would make the diagram more difficult to understand.

What does the microphone do? Early broadcasting was done with telephone transmitters, but today they are not sensitive enough for the many kinds of sound sent over the radio. One microphone now in use consists of two metal plates which are electrically charged and so arranged that the one in front is moved by the vibration of the sound waves. Vibration of one plate changes the strength of the charge in the other. This microphone contains a radio tube which makes the current stronger.

Exercise. *Copy the diagram of a sending station in your notebook, and label all the parts named in the text. Make your drawing exactly twice as large as the one on page 612. Use your ruler to make the lines straight and the measurements accurate.*

Science activity. Arrange with a commercial broadcasting station or an advanced amateur in your neighborhood to observe a transmitting station in operation. Do not waste time listening to the radio performers, but try to find out what makes the machinery work.

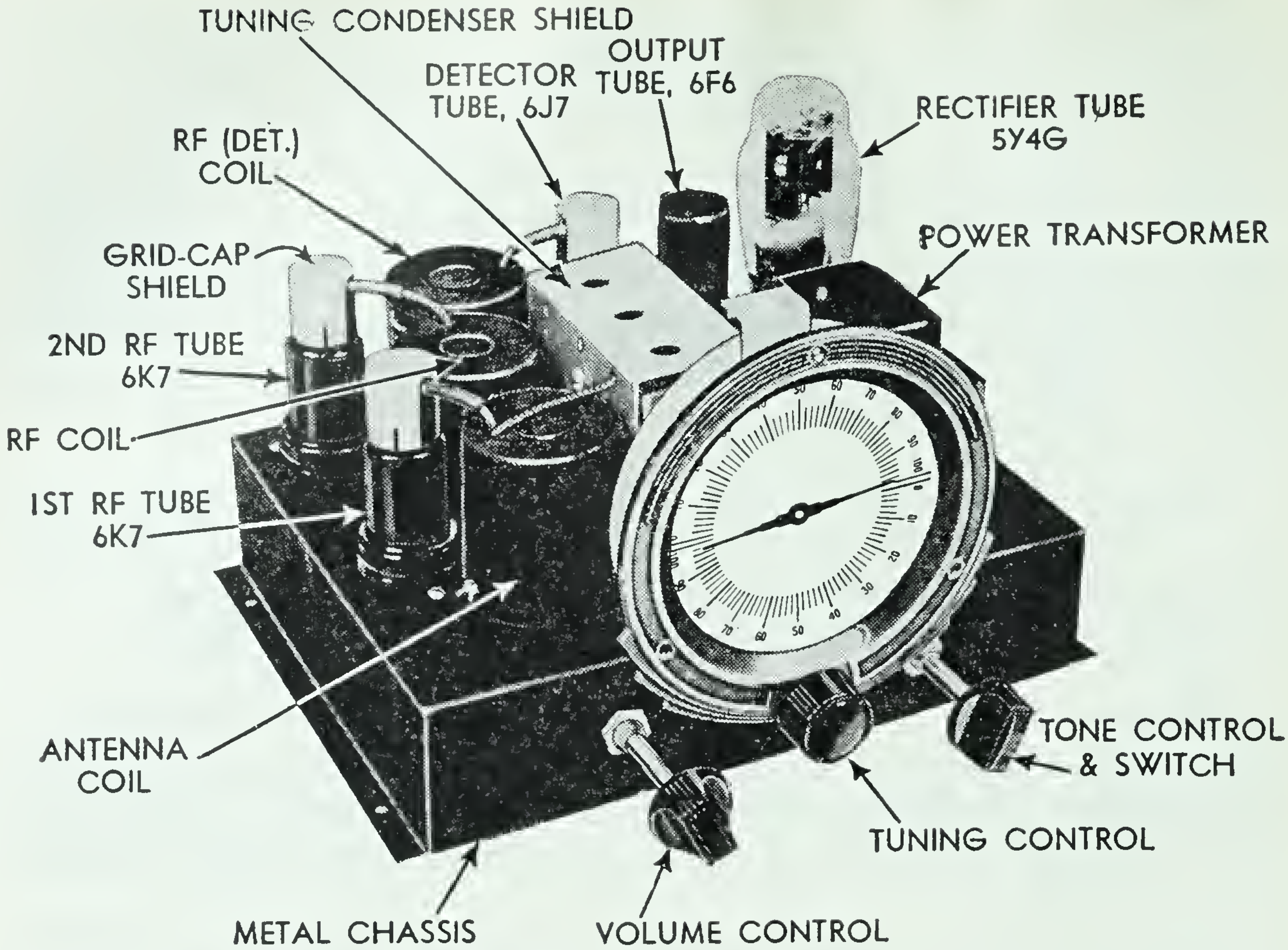
6. How does the radio receiving set work?

The process in the receiving set reverses to some extent the process of the sending set. A current comes into the aerial, is changed and increased in strength, operates a loudspeaker which is much like a telephone receiver, and produces sound waves.

Why use an aerial? The aerial collects the radio waves from the sending station. The sending aerial has a high-voltage, alternating current flowing through it. Magnetic radio waves travel from this aerial and cut through all conductors, producing very weak alternating currents in them. The current produced by broadcasting stations is largely wasted, and that which comes into the aerials of receiving sets is very weak indeed.

The current flows from the aerial to the earth through a ground connection.

What does the radio receiving set consist of? The simplest possible set consists of one tube. The current from the aerial flows through an induction coil which is connected to the grid. The aerial current controls the charge of the grid, changing the strength of its negative charge.



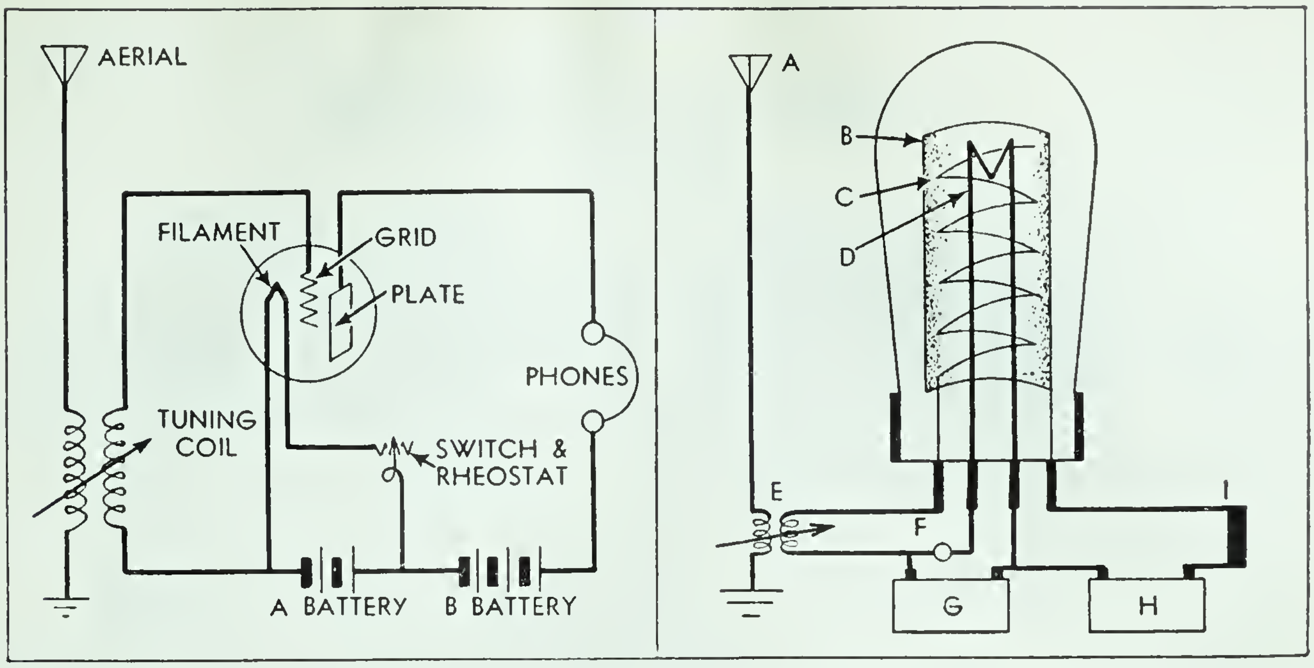
Courtesy Meissner Manufacturing Co.

This simple radio set is one that can be made by an amateur. The parts are labeled with the names to indicate what one would ask for in buying parts.

When no program is received, a steady current flows through the radio tube, which is essentially the same whether used for detecting the current or amplifying it or producing it. The same three parts are always connected in the same general way to the A and B circuits.

The current flowing through the radio tube, as it is controlled by the charges in the grid, flows through a telephone receiver or headphone and produces sound waves. The tube, and the condensers working with it, combine the many alternating current cycles into a smoothed wave and change them to a pulsating direct current which will operate the magnet of the receiver or headphone.

The commercial or regular radio is different in many ways from the simple one-tube radio. It has many tubes, it does not have batteries, and it has a loud-speaker instead of a headphone. The electrical energy is supplied by use of a radio-type tube which changes the alternating 110-volt light



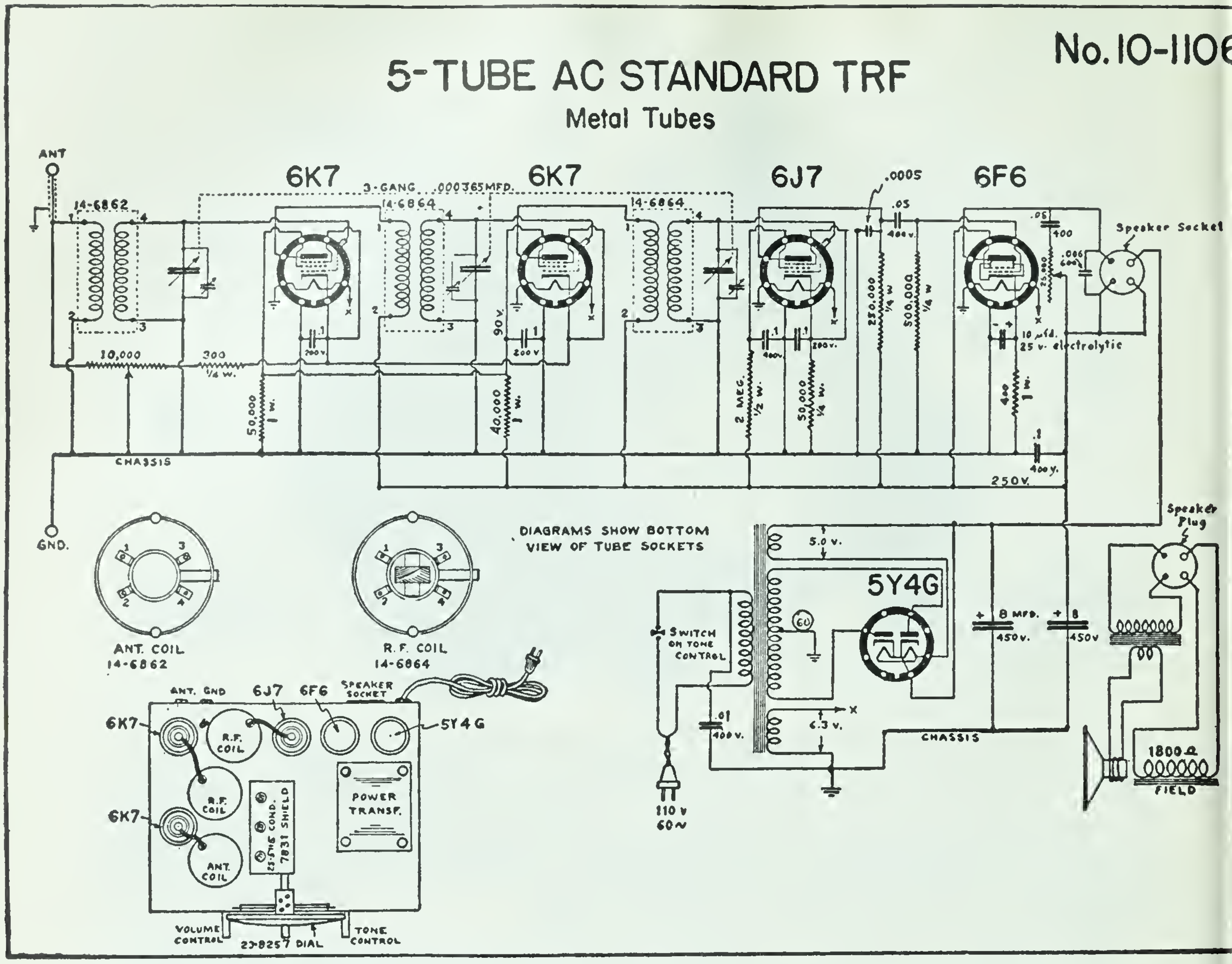
The first diagram shows the parts of a radio receiver with the various parts named. The second diagram shows the same hookup drawn more like a picture and with the parts lettered. Match the letters and the names to be sure you understand the diagrams.

current to direct current. This tube does nothing to bring in the program at all, except to supply the energy to operate the set. Various combinations of transformers, or coils, and coils of resistance wire provide currents of the strength needed in various parts of the radio.

The first tube in a commercial radio is called an amplifier tube and is connected to the aerial to strengthen the energy of the transmitted radio waves enough that they will operate the other tubes. This tube is connected to the grid of a second tube which strengthens or amplifies the current flowing from the first tube. There may be several amplifier tubes, each controlled by the tube before it. In this way, the amount of current that flows through the radio may be greatly increased. With a one-tube set, the current from the aerial is so weak that it cannot control strong currents. By building up the strength of the current in several steps, it is possible to produce the loud sound waves needed for easy hearing.

After the current is built up by the amplifying tubes, it goes through a second tube which changes the many radio waves into waves of the same frequency as sound waves but not actually sound waves. There frequently is an extra-large tube used to give power to the loud-speaker.

The principle of the loud-speaker is exactly the same as



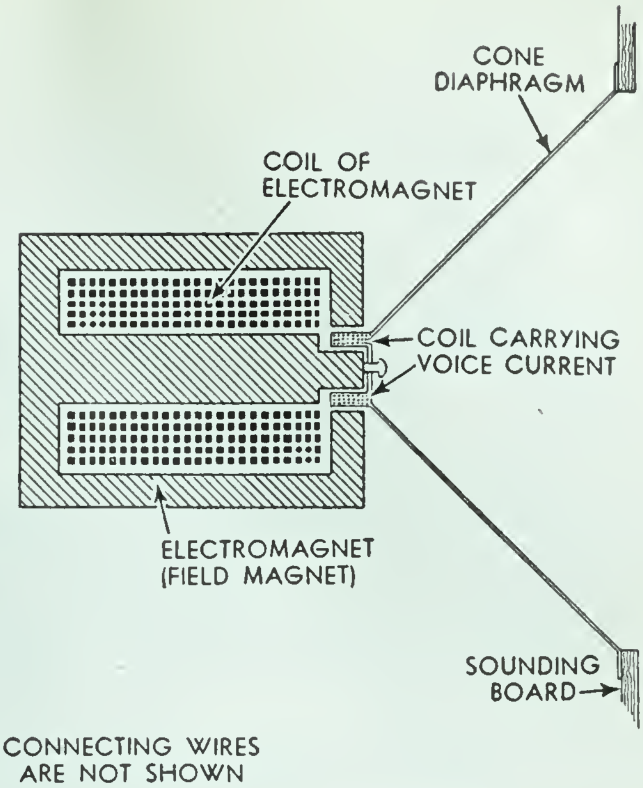
Courtesy Meissner Manufacturing Co.

You are not expected to learn the parts of this diagram. It is put here to help you realize how complex even a simple radio is. This diagram shows the hookup for the set shown in the photograph on page 614.

that of a telephone receiver. Instead, however, of using a soft iron plate to be attracted by the magnet, the electromagnet is mounted on the disk itself. A stronger repulsion and attraction between magnets is possible than between a magnet and unmagnetized iron. There are, in addition to the electromagnet on the disk, field magnets which are kept magnetized by a steady current from a battery or the light socket. The disk is a cone made of a heavy paper. The moving coil, operated by current from the last radio tube, moves back and forth as the current changes, and the strength of the magnetic field changes. The disk vibrates, setting up sound waves which travel through the air.

If the loud-speaker is mounted on a large piece of plywood,

it gives a tone much superior to the tone obtained from mounting the speaker in a cabinet. Commercial radios, even the largest, are not large enough to contain good sounding boards. Some homes of the more expensive type are provided with built-in loudspeakers.



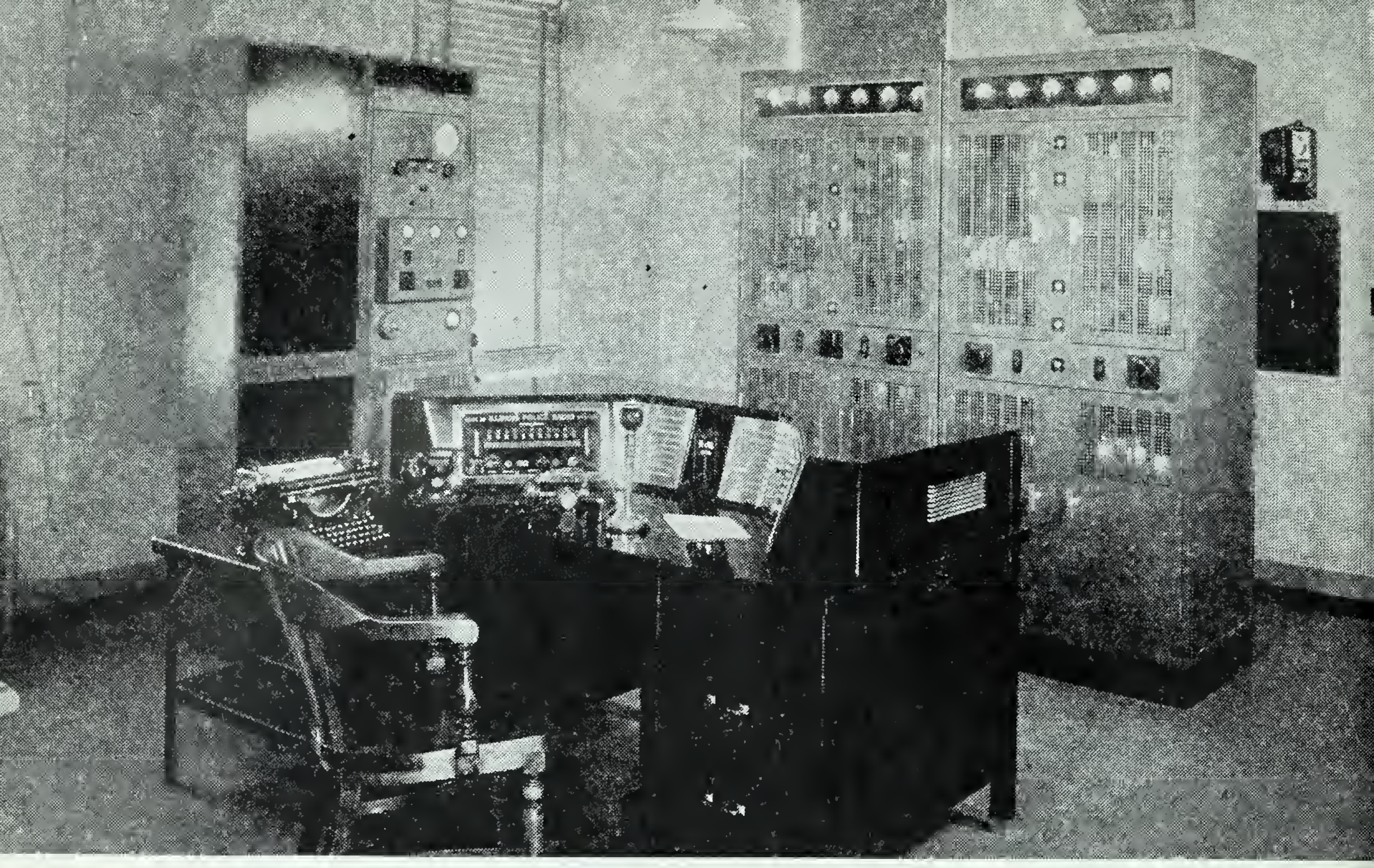
This diagram of the dynamic loud-speaker shows only the essential parts. It consists of two electromagnets which repel and attract each other. The smaller electromagnet is attached to a cone which is vibrated to produce sound waves.

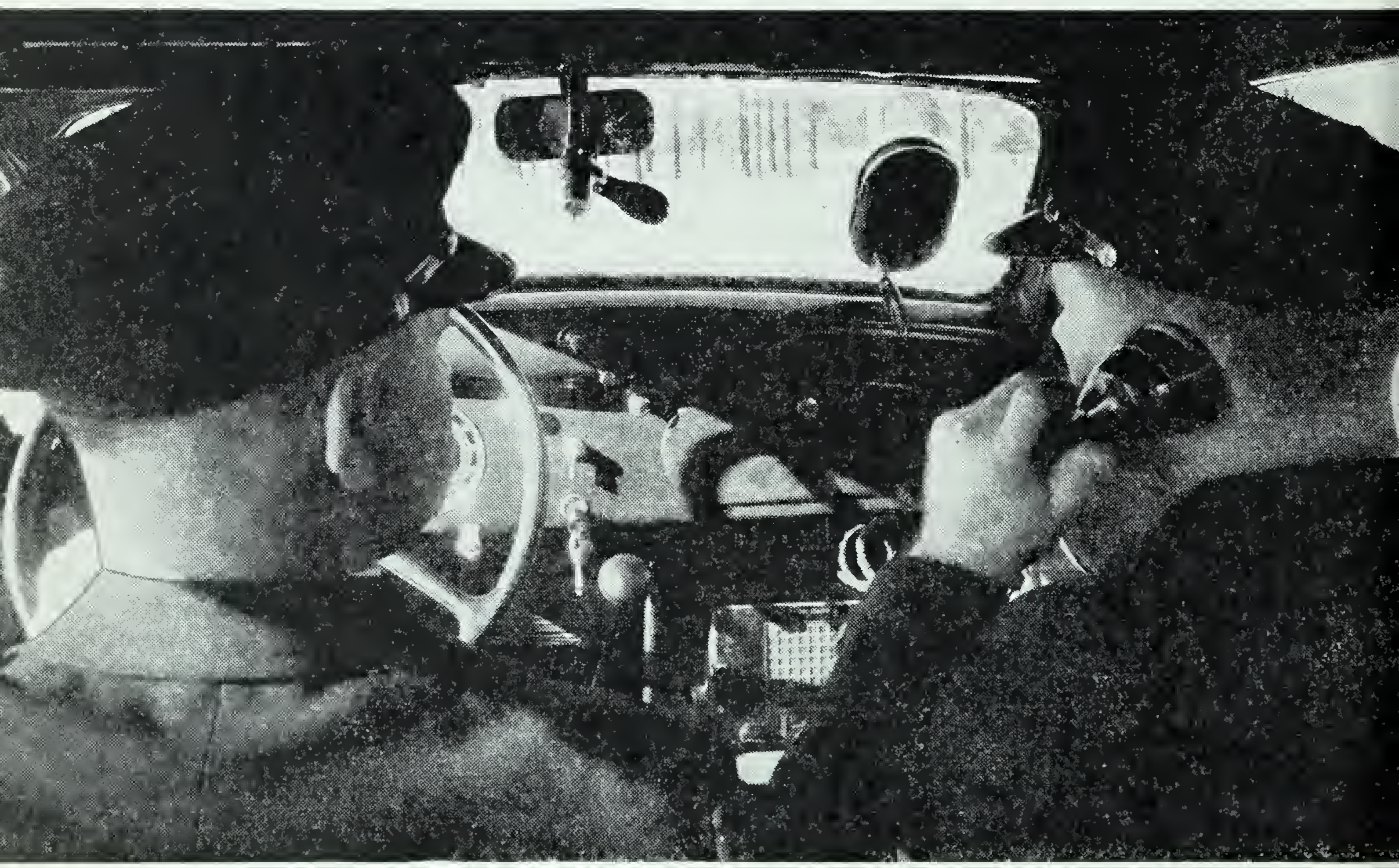
Why must we tune the radio? Each transmitting station is assigned a certain wave length and required by law to do all its broadcasting on that wave length. The length of the transmitted waves is controlled by coils, condensers, and other devices.

Your home radio, on the other hand, will receive a large variety of wave lengths. If it is equipped for both long- and short-wave reception, you can receive waves varying from a few feet up to more than a mile in length. The rate at which the current flows back and forth through the tubes of your radio is also controlled by coils and condensers.

You know that if two tuning forks of the same pitch are mounted together, striking the first will cause the second to vibrate. If they are not of the same pitch, or tuned, the second does not vibrate. Similarly, it is necessary to get the currents flowing through the tubes of your receiving set to alternate at the same rate the sending station currents alternate. When you have done so, by turning a knob which controls a coil or a condenser or both, your set is tuned.

What kind of set should you buy? Because most people enjoy radio, it is probably better to have any set than none at all. Even the poorest set, provided it works, brings in some sounds that can be recognized as speech or music. Many cheap sets have "dummy tubes," that is, tubes which





Courtesy Western Electric Company

The use of radio in law enforcement is increasingly important. The console in the foreground of the picture at the top contains the controls, and the cabinet in the background contains the transmitting apparatus of the Illinois State Police radio network. The radio-equipped squad car shown below is used in Nashville, Tennessee.

are put in to look as if they were of value but which are not connected to the set at all. Even moderately good radios are quite expensive.

Large radios are the only kind which can possibly give faithful reproduction of the original sounds. The best table models, however, produce tones as good as those of poor quality console models. Portable radios give tones of very poor quality and are expensive to operate. In general, the smaller the radio the worse its performance may be expected to be.

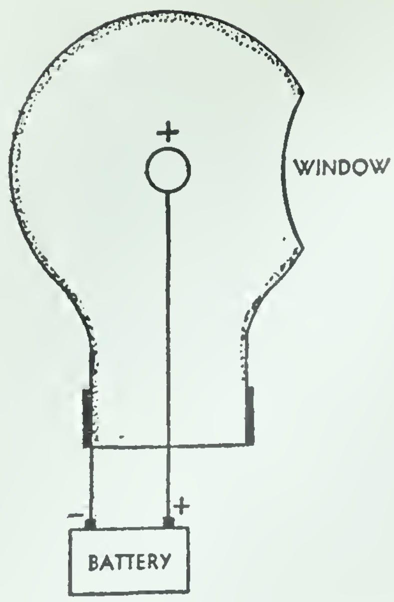
Radio sales appeals are concentrated upon gadgets instead of improvement of radios. There are many devices that may be of some slight value—remote control, the electric tuning eye, short wave, and airplane dials. But these have no bearing at all upon the type of sound produced by the radio, which is the only thing of importance. Unless you are going to become an amateur radio operator, short wave is of little interest; and if you are intending to become a radio operator, you should build your own set. If you cannot build your own set, with the aid of your teachers, shop courses, books, and other amateurs, you probably will not have the ability to become a radio operator anyway.

The radio to buy is the one that gives the best reproduction of the programs from the station to which you want to listen. No radio does everything well. Make up your mind what you want, and get it, paying no attention to nonessentials.

Exercise. *Complete the following sentences:* The radio tube consists of three parts. The —1— is a hot wire which gives off —2— when heated. The —3— is a screen which acts as a valve controlling the flow of —4— from the —5— to the plate. The —6— is always positively charged and attracts the —7—, which are charges of negative electricity. —8— charges repel. The current which flows through the aerial is produced when —9— cut through it. This current is used to control the charge of the —10—. The current which flows from the tube controls an —11— in the loud-speaker.

7. How is the photoelectric cell used in communication?

The photoelectric cell has many uses not connected at all with communication. It is used in the light meter which you



A photoelectric cell.

have already studied. It is used in controlling electric currents which turn on and off electric lights when the brightness of light changes in a room. It opens garage doors when the headlights of a car shine on it. It sorts coffee, oranges, and wool. All these accomplishments sound like the work of a magic lamp but really are caused by light shining upon a layer of chemical in a glass container.

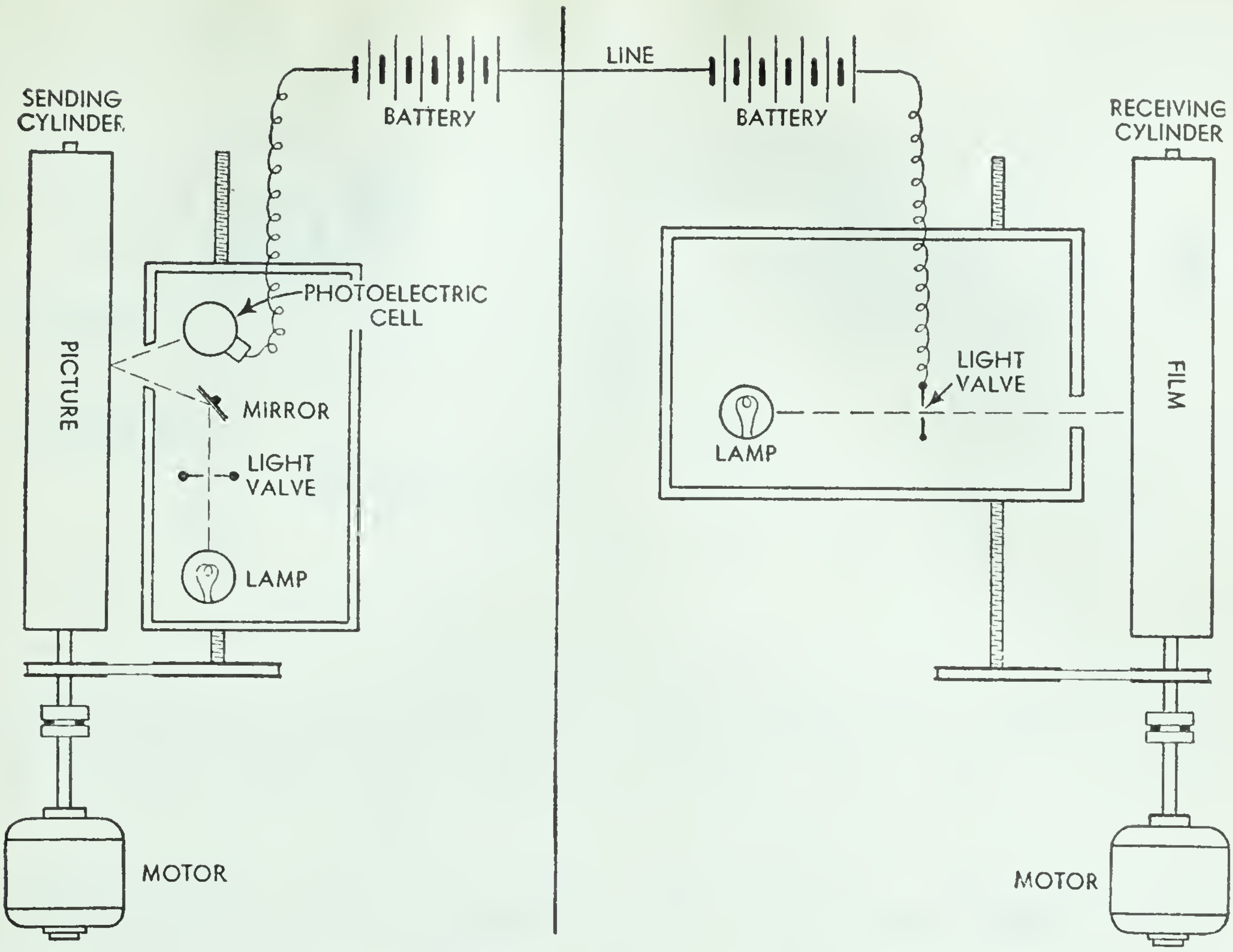
In communication the photoelectric cell is used in wired photos, in radio transmission of photographs, in television, and in talking pictures.

What is a photoelectric cell? The photoelectric cell is one of the simplest devices used in electricity. It consists of a glass tube, the inside of which is coated with a substance which gives off electrons when light shines on it, and a metal plate to receive the electrons. Among substances which give off electrons when exposed to light are sodium, potassium, lithium, selenium, cesium oxide, and copper oxide. Light waves supply the electrons with enough energy to escape from their molecules. When the negative electrons are given off, they are attracted to a positively charged plate inside the tube. The plate is kept charged by a battery or other current source. Some tubes contain argon under low pressure.

Another type of photoelectric cell is not attached to a source of current and is used in the light meter.

The photoelectric cell is connected as shown in the diagram. The inside of the container is coated with the light-sensitive material which is connected with the negative terminal of the battery. The wire loop which acts as a plate is connected to the positive pole. The flow of electrons to the plate makes up a current. The strength of the current is proportional to the strength of the light shining upon the light-sensitive material. When the cell is in the dark, no current flows. Even the strongest current of a photoelectric cell is too weak to do much work.

How are pictures sent by wire? Since the photoelectric

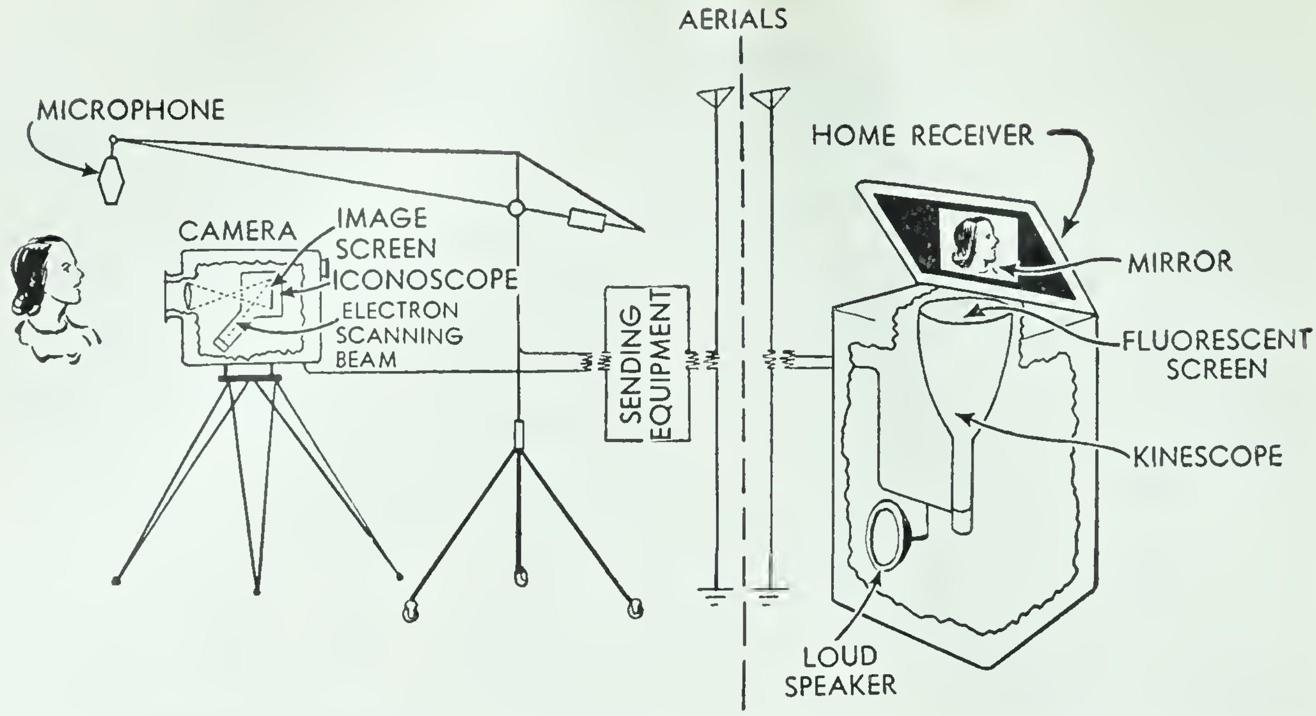


The wired photo apparatus is used for carrying pictures over telegraph or telephone wires. The photograph is put on a revolving cylinder, and a reflected beam of light from the photograph controls the current in a photoelectric cell. The current controls a beam of light which prints a picture on the receiving set.

cell has been perfected, many photographs used in newspapers are sent by wirephoto. One system uses telegraph wires; another uses telephone wires.

The photograph to be sent is fastened on a cylinder which is turned by a motor. A light valve is also operated by a motor. A beam of light from a lamp shines through the light valve on a mirror and is directed on the picture. Where the picture is dark, little light is reflected from it. Where the picture is light, most of the light is reflected. These flashes of light reflect upon the photoelectric cell, which sends a current in proportion to the light received from the picture.

The motor of the receiving instrument is exactly in step with that of the sending instrument. This motor turns the receiving cylinder, on which there is a sensitive photographic film. The current from the photoelectric cell, strengthened by batteries, comes over the wire and opens and closes a light



The equipment used in television has undergone many changes. One system, which is dependent upon electron beams for its operation, is shown here. This is the system that was first commercially satisfactory.

valve through which the light shines upon the sensitive film. If the valve opens wide from a strong current, the spot on the negative is strongly exposed; but if the current is weak, the valve opens slightly, and the spot on the film is only slightly exposed.

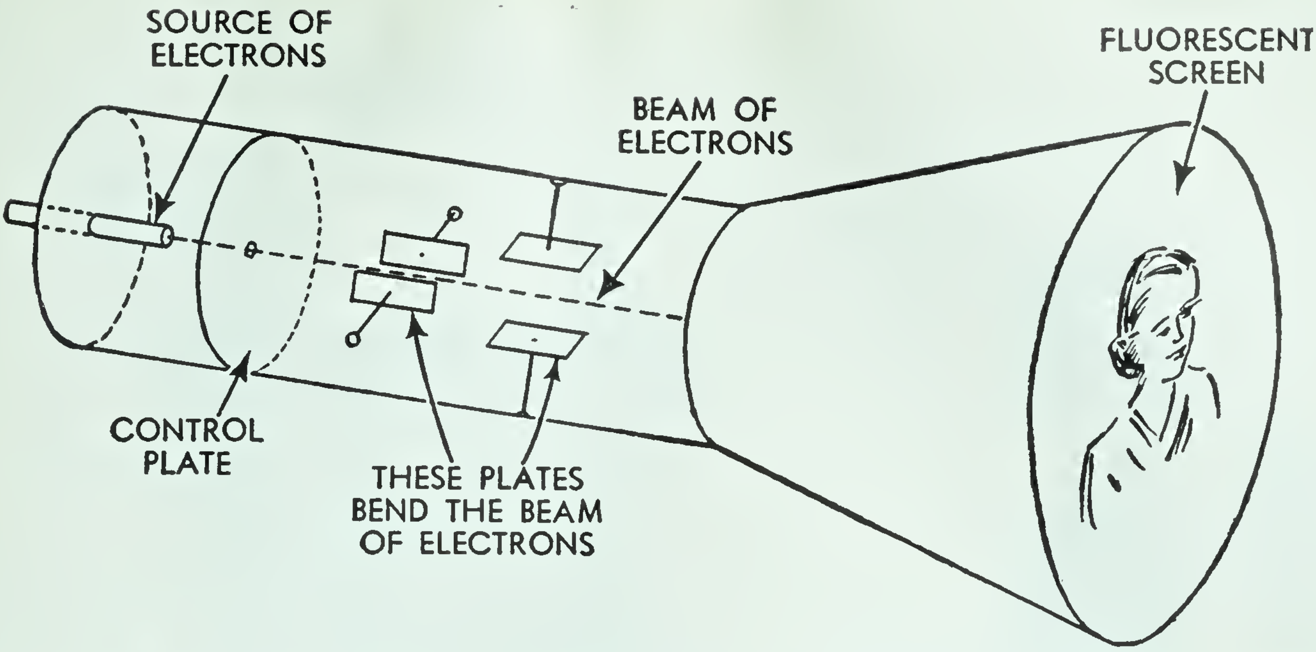
The cylinders move along so uniformly that the beams of light cover every bit of the surface. The sensitive film is developed and printed as any other film is.

Pictures are similarly sent by radio, except that the current is used to operate the circuits in a radio instead of being sent by wire. Many important news photographs from Europe are sent by radio and made available for use in the next morning's papers.

What is television? Television of a sort has been in use for many years, but only recently has it been used for broadcasting to the home.

While it is doubtful that the average person is capable of understanding fully the working of television, we can go over the familiar principles of electricity that we have learned and see how they apply to this complex group of devices.

The television camera shown in the diagram is used to produce the current broadcast by the sending set.

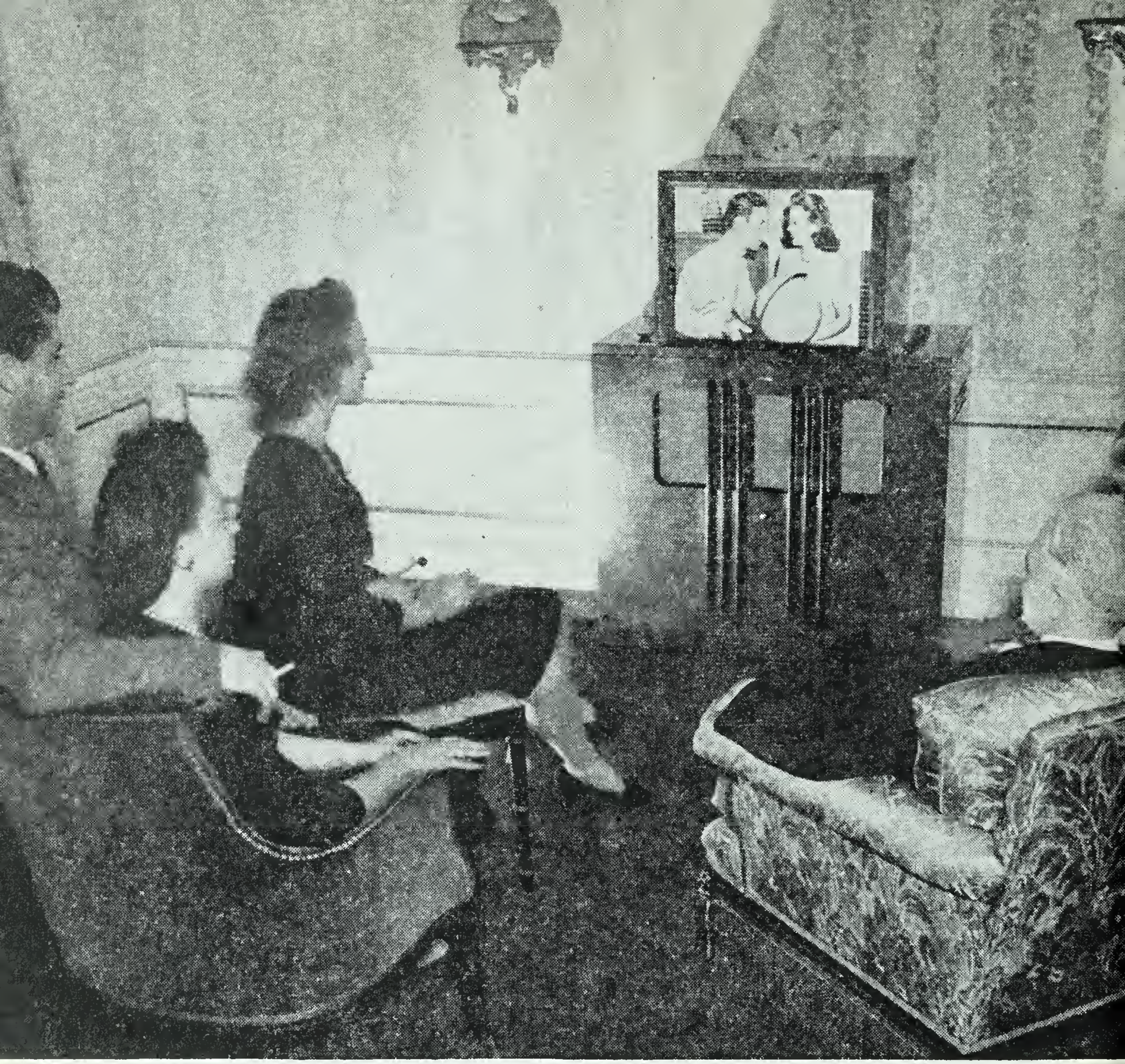


One of the types of receivers used in television is this funnel-shaped tube. A beam of electrons passing between the two pairs of electromagnets moves rapidly over the screen, making a chemical glow to produce an image.

The received radio waves are changed into an electric current. This current is used to operate the receiving tube. It has a flat bottom and sloping sides. In the neck part of the tube there is a plate from which electrons are shot out to the bottom of the tube. The electrons pass through a hole in a metal plate and make a "pencil" of energy which "writes" on the bottom of the tube. The bottom of the tube is covered with a fluorescent mineral, one that glows where the electrons strike it.

To make the pencil of electrons move back and forth and up and down, they are passed between two sets of magnetic plates. One set is at right angles to the other. Now, since electrons are negative charges, the plates can be used to repel and attract them. The positive plates draw the electrons out-of-line so that, by balancing the charges of the two sets of plates, the beam of electrons or pencil may be drawn across the bottom of the tube, making a picture. Some parts of the lines are light and some are dark, just as are the objects in the scene being scanned.

What difficulties delay television? You may think that television is really simple because it consists only of a kind of camera at one end, sending currents of varying strength by radio; and at the other end a receiving tube with some plates and with some paint on the bottom which glows to



Courtesy Radio Corporation of America

The home television program may be received on a screen large enough for several to see at one time, in a room only partially darkened.

produce a picture. Of course this receiving tube must be connected with a radio tuned to the radio of the sending station.

But you know that a picture must be complete for the eye at least 16 times a second to keep it from flickering. Each picture must be made up of hundreds of lines, formed by the beams of light. The speed of movement of the beams is almost beyond our imagination. If only a few beams are used, the pictures look coarse, like those in a newspaper, instead of fine like the pictures in this book. Study a picture in this book under a reading glass, and see how it is built up.

The pictures used in most television receivers are less than a foot square but, even so, the detail at present is not particularly clear.

The television station requires more radio wave lengths than does ordinary broadcasting, and most wave lengths are already in use. The reception of television is limited to short waves, which are comparatively free from static but which are also limited in distance. Static completely ruins television, much more than it does radio. The complexity of the television camera itself is amazing. This machine must throw a series of light or electron beams which cover the picture completely from 20 to 25 times a *second.* Naturally, the movement of the individual beam is so rapid as to be invisible to the eye.

Exercises. 1) *Draw a diagram of a photoelectric cell, and show by a heavy line how the current flows through it and the circuit to which it is attached. Label it with these words:* Positive Loop, Battery, Sensitive Material, Tube.

2) *Complete the following sentences:* When light shines upon the sensitive materials in a —1— cell, —2— are given off which are attracted by a —3— charged ring, producing a —4— across the space within the cell. Television, wired photo, and radio pictures depend upon light reflected from an object falling upon a —5—, which controls flow of current. The current at the receiving wirephoto instrument controls a beam of —6— to produce a picture on film. In television sets, the current controls a beam or pencil of —7— which produces a picture upon a —8— mineral.

8. How is sound recorded and reproduced?

When you go to the neighborhood movie and the sound of the singer's voice comes from the screen or the rifles crack as another villain bites the dust, you are not listening to voices or shots at all. What you are hearing is the sound of vibrating disks moved by electric currents.

There are two types of sound recorders: the phonograph type and the film type.

How are phonograph records made? The first phonograph records were made by talking into a horn or megaphone, causing the sound waves to vibrate a needle against a moving cylinder. The needle scratched a groove in the surface of

the cylinder, which was usually of wax, and made a record of the sound waves. The cylinder was turned by a crank and moved along by a screw. Then the needle was moved back to the beginning, placed in the groove, and the needle was vibrated by the groove, setting the disk to which it was attached into motion and producing sound waves. The dictaphone of today operates on similar principles.

Records are made now by use of electricity. You might imagine a needle attached to the vibrating disk of the telephone receiver being used to cut a groove in a record as it was vibrated. This is the general principle involved in making records.

The record is made of perfectly smooth beeswax. The needle is mounted on an arm which is moved with a worm gear to make the grooves in the record the right distance apart. The wax record is mounted on a turntable which turns at an even speed.

When all is ready, the program or speech to be recorded is played or spoken into a microphone. The current from the microphone is amplified by radio tubes to make it strong enough to act through an electromagnet and vibrate the cutting needle. As the disk turns, the needle vibrates and cuts a groove that wavers from side to side in the soft wax. The wax shaving is picked up by a vacuum cleaner device to prevent it from sticking and spoiling the record. Two records are made at the same time.

One record is played, and if it sounds all right it is melted down and used for wax. Playing a soft wax record spoils it for further use. The second record is covered with carbon and electroplated to make a metal master record. Other records are formed by pressing soft plastic or wax against the master record by a molding process.

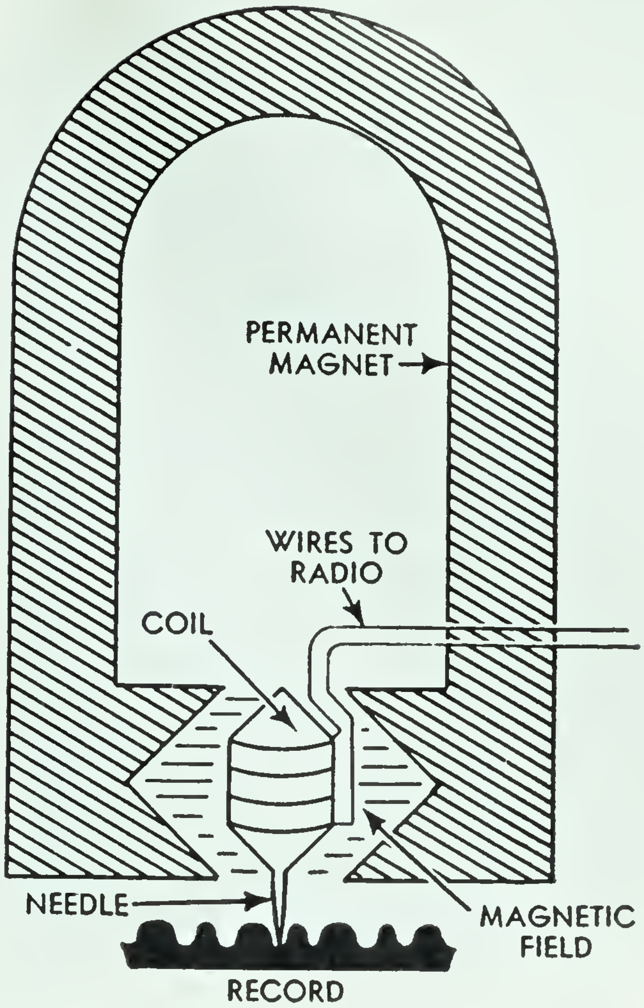
How are records played? The sound reproducer, called a pickup, is a generator of current. One kind consists of a horseshoe magnet, with the ends brought in toward the center. Inside the space between the ends of the magnet is a coil of wire, attached to connections to the loud-speaking equipment. The coil of wire has a core of metal, to which the needle is attached.

When the needle is placed on the moving record, it vi-

brates. The vibrating needle causes the coil of wire to cut the magnetic field, producing a current. The current flows from the coil to the radio system which makes the loud-speaker work. The electric current produces sound waves. The strength of the current flowing into the radio is exactly in proportion to the sounds that caused the grooves to be cut on the record.

You may have an electric phonograph at home which plays through your radio. Any radio may be made into a phonograph by adding a turntable, turned by a motor, and by connecting it properly to the radio. This connection takes the place of the aerial.

To make sure that the sound comes from the right direction in the theater, the loud-speaker is placed behind the theater screen. Theaters are wired to carry current from the projection room to the screen.

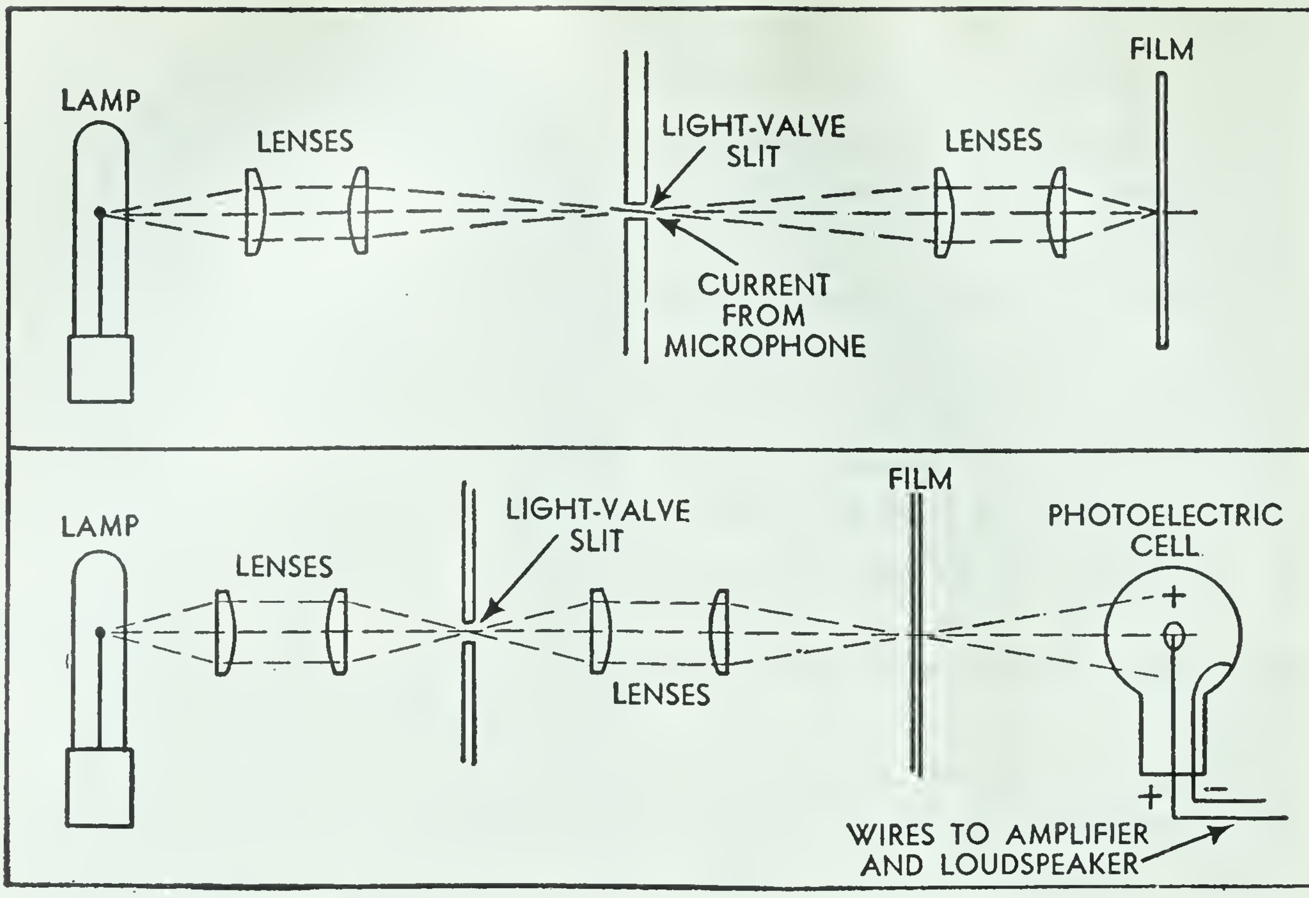


This phonograph pickup operates on the principle that when a conductor cuts a magnetic field, a current is produced. The coil is vibrated by the needle moving in the groove of the phonograph record.

There are also other kinds of pickups. One of them uses a mineral crystal instead of an electromagnet to control the current to the radio tubes. Another employs a photoelectric cell, a beam of light, and a mirror to produce the current which controls the radio.

How is sound recorded on film? To record sound on film, the same setup of microphone and amplifier tubes is used that is used for recording the sound on a disk record.

As you know, to make a mark on film, light must shine on the film. To shine light on film, a light gate is used somewhat like the one in the wirephoto. A lamp gives off light, and



Current from a microphone causes a beam of light to expose the film to make the sound track (*top*). The microphone current opens and closes the light-valve slit. The sound projector (*bottom*) causes a light to shine through the sound film onto a photoelectric cell which produces a current to operate a radio amplifier, connected to a loudspeaker behind the movie screen.

lenses cause the light to shine through a slit onto the edge of the film. There is a magnet on either side of the slit. In front of the slit are two metal ribbons, weaker and thinner than a spider's web. The current from the microphone and amplifiers cause these ribbons to move together or apart, depending on the magnetic charge, thus exposing the film to varying amounts of light. The film moves along at constant speed. On the edge of the film the sound track is printed as a series of lines—some close together, some farther apart, some wide, some narrow. The slit through which the light shines, when not covered by the metal ribbons, is two-thousandths of an inch wide.

Another type of film recorder uses a swinging mirror instead of a slit. The current swings the mirror. This arrangement causes the sound track to be shaped like the teeth of a jagged saw.

What is the monitor? When sound is being recorded on film, the sound engineer listens to the sound through a mon-

itor. The monitor is a radio equipped with earphones. The light that shines through the transparent film falls upon a photoelectric cell and is connected where the aerial of a radio would ordinarily be found. Thus the light is transformed into current which produces sound waves. If the sounds do not come through the monitor correctly, necessary changes may be made to prevent spoiling the film.

Courtesy Dictaphone Corporation

The dictaphone is a phonograph which records the voice in taking dictation. The machine seen here reproduces it for the typist. The typist listens and writes on the typewriter what has been recorded on the record.

How do we project sound film? The sound film is run through the projector in the theater. A light shines through a light slit on a photoelectric cell. The film passes in front of the slit in such a position that the beam is interrupted by the black lines on the film. As the beam of light is interrupted, the strength of the current flowing through the cell is changed. The changing current is used to operate the radio system which produces the sound in the loud-speakers.

Although the movement of film through the projector is jerky, a long loop is formed which is moved steadily along by a second motor, preventing damage to the film. The sound is 19 frames ahead of the picture. The sound projector and picture projector are separate systems housed in one machine.

How do ordinary phonographs work? There are many of the old-type mechanical phonographs available and in use for picnics, in cabins, and where there is no electric power available. These phonographs consist of a spring-driven motor, a turntable, a reproducer, and a horn. The spring is

wound up, and the motor is started by releasing a brake. The record is placed on a turntable, which whirls around. The needle is attached to a disk in the reproducer, and the grooves of the record vibrate the needle to produce sound waves. The horn increases the volume and resonance of the sound. One can play a phonograph record with the sharp corner of a calling card.

When playing a phonograph, new needles should always be used, for a dull needle becomes broad and blunt, and scrapes away the sides of the grooves of the record.

Of what value are records? Sound recordings have a historical value much greater than that of still pictures or print. Sound brings an illusion of life and reality that can be obtained in no other way. There are available today collections of records of great historical value.

Exercise. *Complete the following sentences:* In making records, sound waves are picked up by a —1— which controls an electromagnet. The electromagnet moves a —2— back and forth, causing it to cut —3— in a revolving beeswax —4—. The disk is electroplated with —5— and used to make other records. The pickup contains a —6— and a coil which moves to produce a —7—, which is amplified and changed to sound by radio tubes. The film sound track is made by —8— passing through a slit and shining on the film. The size of the slit is controlled by the current from a —9—. When the film is run, light shines through it upon a —10— which controls a radio-operated loud-speaker.

Science activity. Arrange to visit your local theater or your school projection booth, and observe the operation of the sound equipment. Find the loud-speakers, and learn how they are wired from the projection booth.

A Review of the Unit

Sound is a form of physical energy which travels in waves through the air or through other materials. It is produced by vibrating bodies. Pitch of sound depends upon the rate of vibration, the lowest sound we can hear being 16 vibrations per second and the highest about 20,000 per second. Pitch of strings is raised by tightening the string, shortening it, or reducing its cross section.

The telephone and telegraph depend upon use of a sender to change the strength of a current, a conductor to carry it, and a receiver containing an electromagnet to produce sounds.

The radio broadcasts magnetic waves set up by a current flowing through an aerial. The strength and frequency of the waves are controlled by a radio tube, which in turn is controlled by a microphone. The waves cut the aerial of the receiving set and are changed by tubes to current which controls an electromagnet in a loud-speaker.

Sound is recorded on a record by making grooves in it. The grooves cause a needle to vibrate when the record is played.

Television, wired pictures, and talking motion pictures depend upon use of the photoelectric cell, which produces a current in proportion to the strength of the light shining upon it.

An exercise in thinking

Match the principles and related ideas, according to the directions given in the review at the end of Unit I.

List of principles

A. Sound is produced by vibrating bodies.

B. The energy producing sound causes waves in air and other objects.

C. Pitch depends upon the number of vibrations per second.

D. An electric current is a flow of electrons.

E. The strength of the magnetic field surrounding a current depends upon the strength of the current.

F. When a conductor cuts, or is cut by, a magnetic field, a voltage is generated to produce a current.

G. Like charges or poles repel.

H. Unlike charges or poles attract.

I. The strength of a current varies inversely with the resistance.

J. Electrons are given off when the balance of atomic energy is upset by heat or light.

List of related ideas

1. The voice is produced by the vocal cords.
2. A current flows in a photoelectric cell when light shines on it.
3. Sound waves can set objects into vibration to produce sound.
4. The phonograph pickup is a coil within a magnetic field.

5. A current flows from the filament to the positive plate of a radio tube.

6. Echoes are prevented by use of porous materials in auditoriums.

7. No electrons flow from the filament to the grid of a radio tube.

8. The varying current in the receiver produces sound waves.

9. The ribbons of a light valve are controlled by electricity to open and close them.

10. The telephone transmitter contains carbon grains which are moved by a vibrating disk.

11. Sounding one tuning fork may cause another of the same pitch to vibrate.

12. The rate of vibration of strings is increased by tightening them.

13. The loud-speaker contains a coil carrying a current, placed in a magnetic field.

14. The coil of a loud-speaker vibrates a disk.

15. In wired photo a beam of light is reflected from a photograph to a photoelectric cell.

16. Current strength decreases rapidly as distance from the telegraph station increases.

17. The armature of the telegraph sounder moves when a current flows through the coils.

18. An alternating or varying current flowing through a primary wire produces a voltage in the secondary coil of telephones, radios, and other devices.

19. Sound produces vibration of the parts of the ear to stimulate the nerves of hearing.

20. Hearing aids sometimes conduct sound through the bones of the head.

21. The faster a siren disk is turned, the higher the tone produced.

22. Middle C is 256 vibrations per second.

23. Electrical energy travels over telephone wires to produce sound waves in a telephone receiver.

24. In a telephone receiver coils of wire carry current during speech.

25. Radio waves travel from an aerial carrying a current.

26. Radio waves striking an aerial cause changes in the charge of the grid.

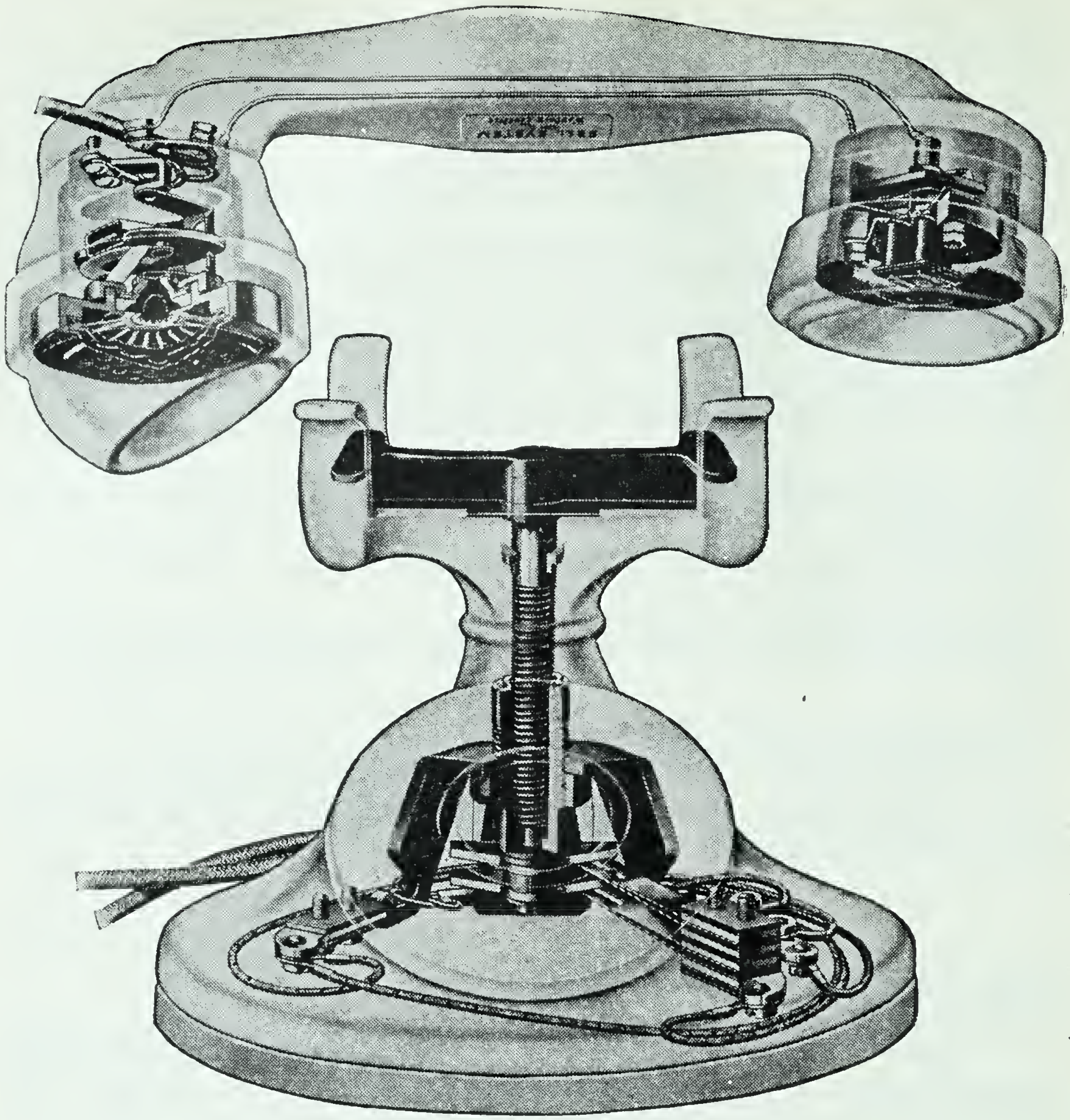
27. No current flows from filament to plate unless the filament is hot.

28. A phonograph record is cut by an electric recording device.

29. The needle of an ordinary phonograph is vibrated by the grooves of the record.
30. The central loop of a photoelectric cell is always positively charged.
31. Charged plates bend the beam of electrons in a television receiving tube.
32. Putting a vibrating tuning fork on a glass makes the sound louder.
33. The vocal cords of a woman usually vibrate faster than do those of a man.
34. Singing near a piano sometimes produces a sound in the piano.
35. Electrons flow from the photoelectric cell to the theater loud-speaker.
36. Light shines through the film upon a photoelectric cell to produce sound in the theater.
37. Shouting into a large pipe makes a sound that lasts a long time.
38. Fish can hear sounds of oars.
39. The longer a string, the slower its rate of vibration.
40. The loudness of the sound depends upon the amount of energy used to produce the sound.

Some things to explain

1. Explain this statement: The development of improved communication and transportation, as the United States was being settled, is directly responsible for the various sections of the country remaining under one flag.
2. Which is of the more practical importance today, wired photographs or television?
3. What do you think is the most important simple electrical device used in communication?
4. Do you think that the radio is being used for the good of all the people or only for the good of advertisers?
5. Describe the operation of an amateur short-wave station in your community.
6. Does a molecule of air in a sound wave travel like a bullet or like a person in a swing?
7. Learn how different animals make sound, and report to the class. Study the cricket, the frog, the dog, and the canary.
8. What is the reason that snow crackles underfoot?
9. What is static? What new type of radio has no static?



Courtesy Western Electric

Can you recognize the various parts of a telephone?

Some good books to read

Bragg, Sir William H., *The World of Sound*
Compton's Pictured Encyclopedia
DeSoto, C. B., *Calling CQ, Adventures of Short-Wave Radio Operators*
Henney, Keith, *Principles of Radio*
Marshall, L. C., *The Story of Human Progress*
McKay, H. C., *Amateur Movie Making*
Meister, M., *Magnetism and Electricity*
Mills, John, *The Magic of Communication*
Mills, John, *Through Electrical Eyes*

Petkin, W. B. and Marston, W. M., *The Art of Sound Pictures*
The Radio Amateur's Handbook, American Radio League
Van Dyck, A., *The Mysteries of Television*
Webster, H. H., *The World's Messengers*
Williams, H. S., *The Story of Modern Science*
Wood, E., *Sound Waves and Their Uses*
Woodbury, D. O., *Communication*
World Book Encyclopedia
Yates, R. F., *A. B. C. of Television*

Some interesting motion pictures

Sound Waves and Their Sources. Erpi (*16 sound*)
Fundamentals of Acoustics. Erpi (*16 sound*)
Wizardy of Wireless. (2 reels) General Electric Company (*16 silent*)
Speeding Up Our Deep-Sea Cables. (2 reels) Western Electric Company (*16 silent*)
Inside Story of Your Telephone. (2 reels) Western Electric Company (*16 silent*)
Voices In the Air. Bell Telephone Company (*16 sound*)
Voices of the City. Bell Telephone Company (*16 sound*)
Flying Telephone. Bell Telephone Company (*16 sound*)
Modern Knight. Bell Telephone Company (*16 sound*)
Far Speaking. Bell Telephone Company (*16 sound*)
Sky Harbor. Western Electric Company (*16 sound*)
Family Album. Western Electric Company (*16 sound*)
Voice that Science Made. Western Electric Company (*16 sound*)
Network Broadcasting. Bell Telephone Company (*16 sound*)

Some related lantern slides

Sound. Keystone View Co.

Courtesy *Ladies' Home Journal.* © C. P. Co.

UNIT TWELVE

HOW DOES MAN CONTROL HIS LIVING ENVIRONMENT?

AT ONE time in the history of the earth man was competing directly with other animals for food and shelter. Early man probably ate whatever he could find—berries, small animals, eggs, nuts, plants, fish, and any of the larger animals he was able to kill. In these remote days man was at the mercy of his environment and under the constant necessity of fighting a battle that was little better than even.

Today the struggles of early men to obtain food are nearly forgotten. We no longer hunt our food. We do not run when we see large animals. We do not drop to our hands and knees to dig into the soil for some choice bit of vegetation. It is not necessary for us to spend long hours every day sitting patiently by a lake or creek to catch a few fish in order to eat. We are not forced to dig in decaying logs in search of grubs because other food supplies have failed us.

Our clothing is not made of crudely dried and tanned hides. Instead, it is made of plant or animal fibers carefully produced for maximum strength, beauty, and comfort.

We use plants and animals to increase our enjoyment. Our gardens, trees, and parks make our surroundings more pleasant. Bird study is a popular hobby.

Instead of adapting ourselves to life on a primitive scale, we are gaining control of our living environment. There are four important steps in this process. We kill certain animal enemies to safeguard our lives or our food supply. We domesticate plants and animals for bearing burdens and for supplying food and clothing. We protect beneficial plants and animals from becoming extinct so that the supply will not be exhausted. We seek to improve domesticated plants and animals by control of their heredity and by good care.

We must not assume that the work is complete or that we have reached the limits of improvement of our living environment. Quite the contrary is the case. Our farms yield smaller crops than need be. We are killing some animals which should be protected. Many of our enemies—particularly insects and parasitic plants—are not under complete control and never will be. Even so, our success in controlling our living environment is just as amazing as is our success in invention of machines.

Wheat is our most important bread grain. In many places wheat is still harvested with a binder which makes the bundles shown at the top. Below, the grain is being threshed to separate it from straw.

1. Of what value are domesticated plants and animals?

Our civilization is based upon domestication of plants and animals, for man gave up his roving life as a hunter when he acquired flocks of animals and farm crops to tend. A fixed place of living has made possible development of true community life.

What are the important plant groups? Farm crops may be classified in five groups. The first is the grass group, which is the most important group of food plants in the world. It contains such grains as corn, wheat, and oats, and the principal pasture and hay crops. The second group includes the legumes—peas, beans, alfalfa, and clovers. These plants bear their seeds in pods. In a third group are the plants which store food in their roots and stems—beets,

turnips, carrots, and potatoes. the fourth group includes the fruits—apples, peaches, strawberries, and many others. A fifth group includes those plants which are raised for their leaves—cabbage, lettuce, and spinach.

A modern barn and silo are used to keep farm crops safe for use. The ensilage is put into the silo from above by means of an elevator-type conveyer.

What are our food plants? Corn is one of America's contributions to the food supply of the world. Although it was first raised by the Indians, it is now grown in many parts of the world. In the United States corn is the greatest of the food crops, with a market value greater than that of all the other grains combined. The average annual yield of corn in the United States is more than two billion bushels, and its average market value for one year amounts to about a billion dollars.

More than 85 per cent of the corn crop is fed to livestock, about half to hogs, most of the remainder to horses and cattle. Food parts are not only the grain but also the stalks, leaves, and husks. These are either fed to the animals green, field-dried, or made in ensilage. Ensilage is made by chopping a plant into small pieces and storing it in a tank called a silo until it ferments by a process similar to the curing of sauerkraut.

Corn is also used for human food. It provides a really surprising variety of foods: starch, corn sugar, sirup, corn oil, and, of course, corn meal and corn flakes.

There are more than a thousand varieties of corn known, all derived from the original Indian varieties. The three chief types of corn are dent corn, sweet corn, and popcorn.

Wheat is the principal bread grain for the people of the United States. The annual yield is nearly a billion bushels. Wheat has been cultivated since the earliest historic times.

There are two classes of wheat grown in this country. Winter wheat is planted in the fall and harvested the year following in the late spring or early summer. Spring wheat is planted in the early spring and harvested in the late summer or early fall. Because the winter wheat matures earlier in the summer, it is less likely to be injured by rusts and drought. Winter wheat is generally grown in the warmer wheat-growing sections and spring wheat in the colder.

Because of the different kinds of flour made from the kernels, wheat is divided into two groups: hard wheats and soft wheats. Flour from hard wheats is especially valuable for making bread. That made from soft wheats is especially desirable for pastries, biscuits, and crackers.

The legumes, because they contain proteins in large amounts, are an important food for both humans and animals. Beans, peas, lentils, lima beans, and soybeans are common table vegetables. Peanuts are eaten not only as a between-meal food but as a source of cooking and salad oil and to provide peanut butter, an excellent food. Clovers, alfalfa, and field peas are commonly fed to livestock, either as hay or as ensilage.

What are our important fruits? The United States is the leading fruit-producing country in the world and the apple is our most important fruit crop. The value of this crop is twice that of any other fruit. We raise about four bushels of apples for every family or one bushel for every person. We raise a bushel and a half of peaches, a bushel of pears, 125 pounds of grapes, and eight quarts of strawberries for every family. More than 80,000 freight-car loads of oranges are produced annually.

What are some other uses of plants? Some plants are used to provide clothing. Cotton is the most important of these crops. More than half of the cotton crop of the world is raised in the southern part of the United States. Cottonseed meal is used as a feed for farm stock and as a fertilizer. Cottonseed oil is used in cooking and for making soap and washing powder.

Flax is important because it furnishes linen and linseed oil. Hemp furnishes fiber for rope and mats.

What are our best food animals? Cattle are the most im-

portant source of animal food, for they provide meat, milk, butter, and cheese. There are two classes of cattle: dairy breeds and beef breeds. Some dairy breeds are noted for the large amount of milk they give; other breeds are famed for the richness of their milk, that is, the amount of butter fat it contains. Cattle are able to feed on rough material, such as hay, which we cannot use as food, and they change it into milk and meat.

Courtesy U. S. Department of Agriculture

These sheep produce four times as much wool as the same number of sheep would have produced less than 100 years ago. Each of these sheep will produce eight pounds of wool a year.

Swine are somewhat better meat-producing animals than are cattle. That is, a given amount of food will make more meat in a shorter time in the form of pork than it will in the form of beef. Pigs can be raised to market size in about nine months. The lard-type hogs are fat and chunky, and a large amount of lard can be obtained from their fat. The bacon-type hogs are tall and lean, and a large amount of lean bacon can be obtained from them. Since the principal hog feed is corn, the Corn Belt is also the hog belt of our country.

The most common farm animal is some kind of poultry. Poultry is kept on more farms and by more families in town than any other group of domesticated animals. Chickens require little room, mature quickly, and require little money outlay and little care. Poultry products in one year amount to more than a billion dollars in value, which is more than the combined value of all the gold and silver mined annually in the world.

The chief poultry animal is the chicken. Ninety-six per cent of the total poultry on farms is chickens. There are three classes of breeds of chickens: the egg breeds, the meat breeds, and the general-purpose breeds. The last named breeds, which are raised for both eggs and meat, are the most popular on American farms.

What are some other uses of animals? Animals were perhaps first used as beasts of burden. The dog seems to

Courtesy U. S. Department of Agriculture

Percheron horses are used for draft purposes on the farm. Horses are of great value for hauling hay, for moving farm produce, for field work, and for keeping soil fertile.

have been the earliest domesticated animal. Cats are perhaps the oldest of the domesticated pets but have no special practical value. The horse is still a valuable animal. Cattle, sheep, and other animals provide leather, cattle being most important. Sheep furnish us with mutton and with wool, which is an important clothing material. Animals are a valuable source of fertilizer, both in the form of tankage (wastes from packing plants) and because of the manure they give off.

Some insects have also been domesticated. The honeybee and silkworm are useful to man.

Has science helped improve domesticated plants and animals? Scientific agriculture is a relatively recent development. For example, in less than a hundred years the pig has been changed from a lean, long-legged, long-nosed, mean-tempered animal to the short-legged, round-bodied, calm farm hog of today. Once a hen that laid 50 eggs a year was considered a good hen. Today many flocks average more than 200 eggs per hen per year. The Texas longhorn is extinct today, and in its place Herefords and Shorthorns produce three pounds of beef where the longhorn produced one. The managers of the scientific or industrial farms use fertilizer to give the plant exactly the food it needs, supply water by irrigation, select a climate where the sun shines,

use machines to do the hard labor, and produce more food per acre than anyone ever dreamed of producing a century ago.

It is estimated that the present average yield of various farm crops can still be increased from one-half to 10 times by better methods of farming. Not nearly all the estimated possible yields have been reached because not all conditions are controlled properly. The best seed and best kinds of plants are not yet fully developed, and the farming methods are not perfect.

Filmstrip: Dairying—The Milk Industry. S.V.E.

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* corn, wheat, cattle, poultry, cotton, farming, yield, fertilizer, domesticate, legumes, grass, civilization.

Science activities. 1) Select some type of farm animal, such as poultry, hogs, or cattle, and read about it. Make a summary report on the varieties, their uses, their differences, and other important information.

2) Make a collection of 25 useful plants and plant products grown in your community.

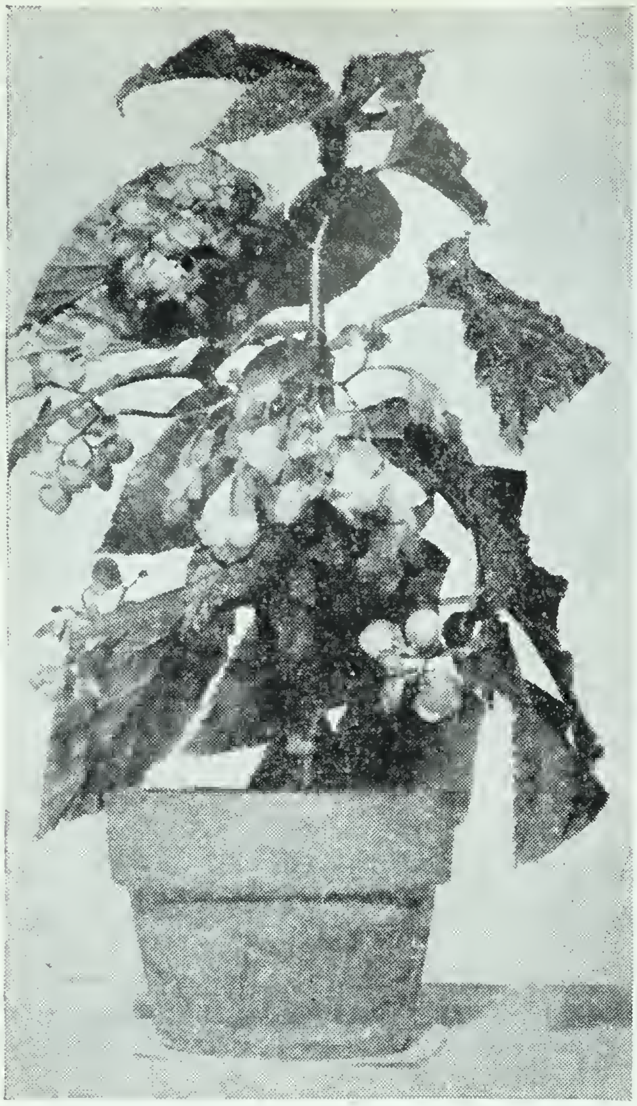
2. What plants are adapted for growth indoors?

While the growing of ornamental plants is of some economic importance, it is of greater importance because of the satisfaction we all receive from contact with living things. Since less than half the people of the United States live on farms, many of us can grow only house plants.

What equipment is needed? The containers used in raising house plants may be either flowerpots or window boxes. If flowerpots are used, the five- and six-inch pots are best, for smaller ones dry out too quickly. Very satisfactory window boxes can be made out of boards. Holes should be bored in the bottom to allow the excess water to escape and collect in a galvanized iron tray placed beneath the box. Before the soil is put into any container, pebbles or other coarse material should be placed in the bottom to provide good drainage.

The various receptacles for house plants may stand on a table or plant stand in front of a window, or they may be

placed on the sill or on shelves or brackets in a window.



The begonia is one of the most desirable house plants. It bears a profusion of pink blossoms and has beautiful foliage. This plant was rooted with the aid of a hormone and vitamin B.

What are the best house plants? In deciding on which plants to select, consider the conditions of light in the room in which the plants are to be kept. If the room is sunny, a great variety of plants may be grown; but if it is shaded, select plants that will do well without much light. Ferns are among the best plants for shaded rooms. Other plants that will thrive fairly well in the shade are asparagus sprengeri, aspidistra, begonia, English ivy, oxalis, and primroses. These will also do well in the sun.

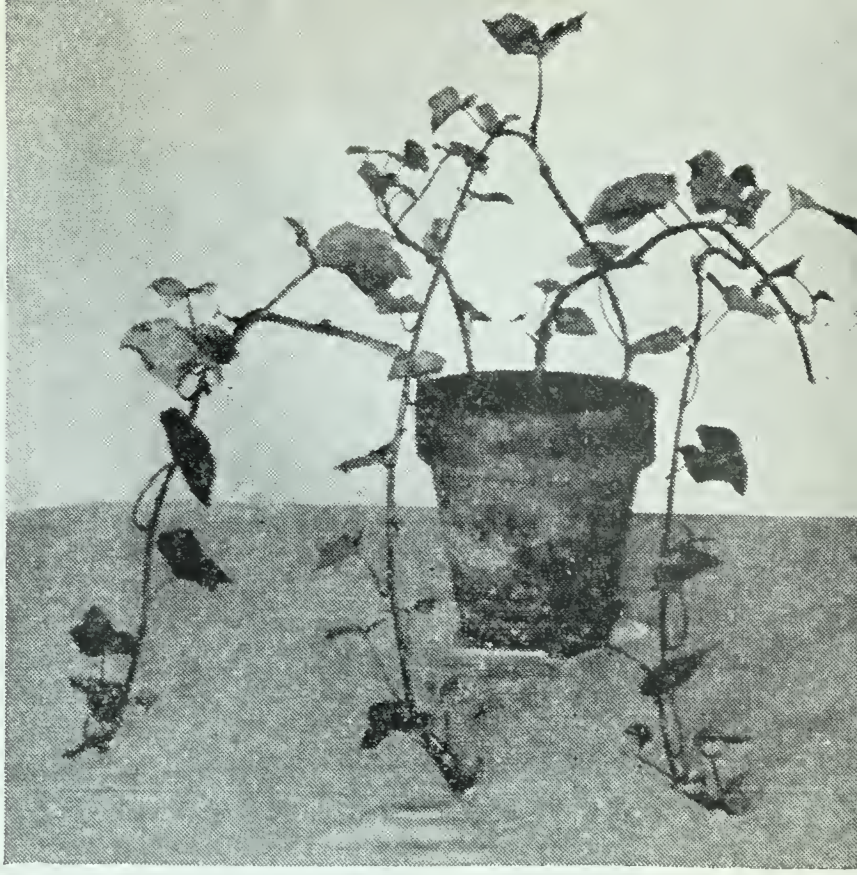
Others that are well adapted for a sunny location are geraniums, heliotropes, wandering Jew, fuchsia, and bulbous plants. In general the plants that thrive best in the shade are those that are raised for their foliage rather than for their flowers.

What bulbs are selected for indoor blooming? Flowers can be easily obtained in the winter by planting bulbs in the fall. A bulb is a large bud which usually grows underground and is made up of overlapping scalelike leaves. Plant the bulbs in ordinary flowerpots, or in a shallow wooden box with holes for drainage. Over the hole in the bottom of the pot place a flat stone or piece of broken pottery, and on this place a few more pieces of coarse material to allow good drainage. Now add a little soil and then set the bulb in place and cover it with just enough soil to conceal the tip.

Set the pots in a dark, cool place, such as a cool cellar, and allow them to remain until the root systems of the bulbs

are well developed. The pots may be covered to keep out the light. Water them occasionally. The bulbs may be set away in the autumn.

The first three bulbs named in the table below will not withstand freezing. The other bulbs will withstand a temperature below freezing.



This English ivy has few and undersized leaves. It was subjected to frequent drying because it is in a four-inch pot and it is also infested with scale insects.

Before bringing the plants into the living room, keep them for a few days in dim light and at a low temperature. Then gradually bring them into the brighter light and higher temperature of the living room. In order to obtain a continuous succession of bloom, different varieties of bulbs may be chosen, or the same variety may be brought in at different times. Keep the plants well watered.

In the following table are given some results of actual experience with a few kinds of bulbs.

BULB	TIME IN DARK	TIME TO BLOOM	TIME IN BLOOM
Chinese lily	2 weeks	5-6 weeks	3 weeks
Paper white narcissus	5-6 weeks	5-6 weeks	3-4 weeks
White Roman hyacinth	7-8 weeks	3-4 weeks	3-4 weeks
Double Roman narcissus	8-9 weeks	4 weeks	2 weeks
Crocus	10 weeks	6-7 weeks	4-5 weeks
Princess Marianne tulip	15-17 weeks	3-4 weeks	3 weeks

Can we grow bulbs in water? The Chinese lily, the paper white narcissus, and the Roman hyacinth may be raised in water. Special glasses are sold for this purpose. In place of these special glasses, one can use a small mixing bowl. Fill it about half full of pebbles. Set the bulbs on the pebbles, pushing them down slightly in the pebbles. Add water till it covers about a fourth of the bulbs, but do not cover the en-

When plants are left in flowerpots for a year or two, they may become root-bound. That is, roots grow until they fill the pot, leaving little room for soil. The remedy is to cut away some of the roots and repot the plants.

tire bulb. Set the bowl away in a dark, moderately warm place until the roots develop. Then it may be brought into the light.

What care do house plants need? For good growth plants need the right amount of water. The soil should not be allowed to become dry nor, on the other hand, should it be saturated. Water the plant thoroughly, until water runs into the drainage pan or saucer. Throw away the water that collects in the pan or saucer. Do not add more water until the soil looks and feels slightly dry on top.

During the cold weather be careful that the plants are not exposed to a low temperature. Because the roots live in such a small amount of soil, fertilizer should be added occasionally. Fertilizers that are especially designed for house plants may be bought. Plants should not be fertilized between November and February, because there is not enough sunlight available for them to use the food.

The more common insects that may occasionally attack house plants are plant lice, mealy bugs, and scale insects. The plant lice can be destroyed by sprinkling tobacco dust on the leaves. Both plant lice and mealy bugs may be removed with a stiff brush, or the plant may be washed with a solution of whale-oil soap or sprayed with kerosene or black leaf 40 in soapsuds. The red spider is a very small animal found with its web on the underside of the leaf. It may be removed by spraying with water under pressure. If the plant is laid on its side on the basement floor or in the kitchen sink, spraying is much more effective.

How may we propagate house plants? Several varieties of house plants can be propagated from softwood cuttings, which are made from the growing parts of the stem. Plant the cuttings in an ordinary flowerpot or in a box three or four inches in depth. The container should be half filled with clean, moist sand, well packed.

To make the cutting, cut off with a sharp knife a growing tip two to four inches long just below a joint. Remove the lower leaves, leaving at least an inch of the stem bare. Make a hole about an inch deep in the sand with a knife, and into it insert the cutting. Then press the sand firmly about it. To reduce evaporation, cover the cutting with a tumbler, leaving a crack under the cover for the entrance of air. Keep the sand moderately moist. When new leaves begin to form, which with a geranium will take about three weeks, the plant may be transplanted.

The geranium, wandering Jew, begonia, carnation, chrysanthemum, coleus, rose, and fuchsia can be easily propagated by cuttings. Cuttings of the wandering Jew and of some geraniums may be successfully started in water and can be transplanted after the roots have formed. Such a cutting must be handled carefully in transplanting because roots formed in water are not sturdy as are roots that are formed in the soil.

Commercial florists speed the rooting of plants by applying to the stem a chemical hormone. There are two such chemicals in use. By using these hormones, the time of rooting can be cut in half, and some plants will form roots with the hormone which will not root at all without it. A hormone is a chemical which regulates growth or other life processes.

Courtesy American Chemical Paint Company

Use of chemical hormones will cause roots to grow on softwood cutting of plants that will not root at all without the hormone. Such a plant is the arbor vitae shown. The two cuttings have each been in the rooting bed for five weeks. Only the one on the right was treated.

Vitamin B_1 is used to promote the growth of roots after they form. Plants may grow almost twice as fast if treated chemically as do untreated plants.

Filmstrip: Growing annual flowering plants. U.S.D.A.

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* drainage, fern, cuttings, aphids, Chinese lily, watering, bulb, propagation, hormone, scale, roots.

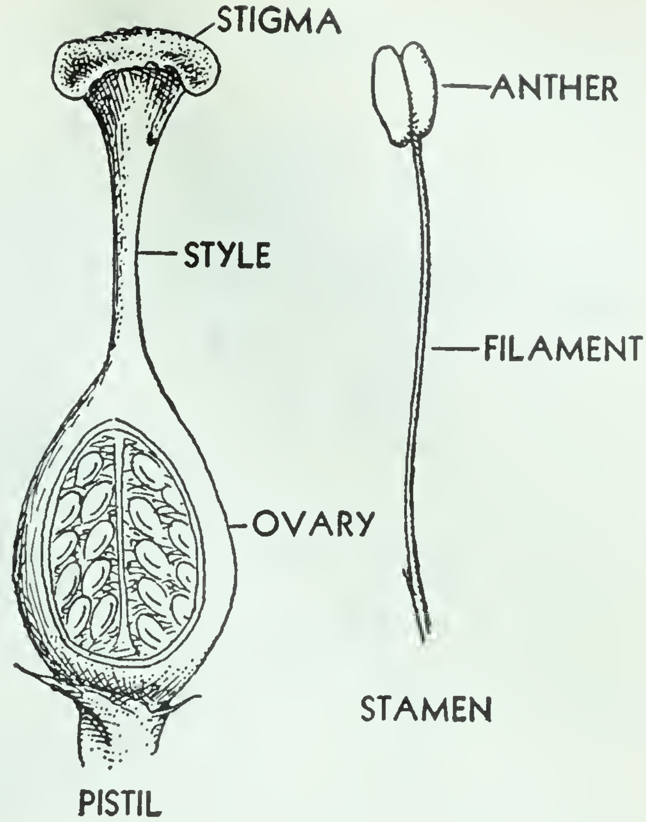
Science activity. Start some house plants in your home. Bulbs are especially easy to grow. Follow the directions given in this problem.

3. What laws control improvement of living things?

When man first domesticated plants and animals, they were not of the same good quality as those we have today. The flesh of swine was tough and strong in flavor. Cattle produced little more milk than was needed by the calves. Grasses produced only a small amount of seed. Flowers were

small and lacking in the brilliance we are accustomed to.

The first attempts of farmers to improve their newly domesticated crops and animals were conducted on a trial-and-error basis. In spite of their lack of a scientific explanation of the working of heredity (passing traits from one generation to the next), they were able to improve some breeds of animals and some varieties of plants to a marked extent. But it was not until the discovery of Mendel's Law that the problem of improvement could be attacked in a scientific manner.

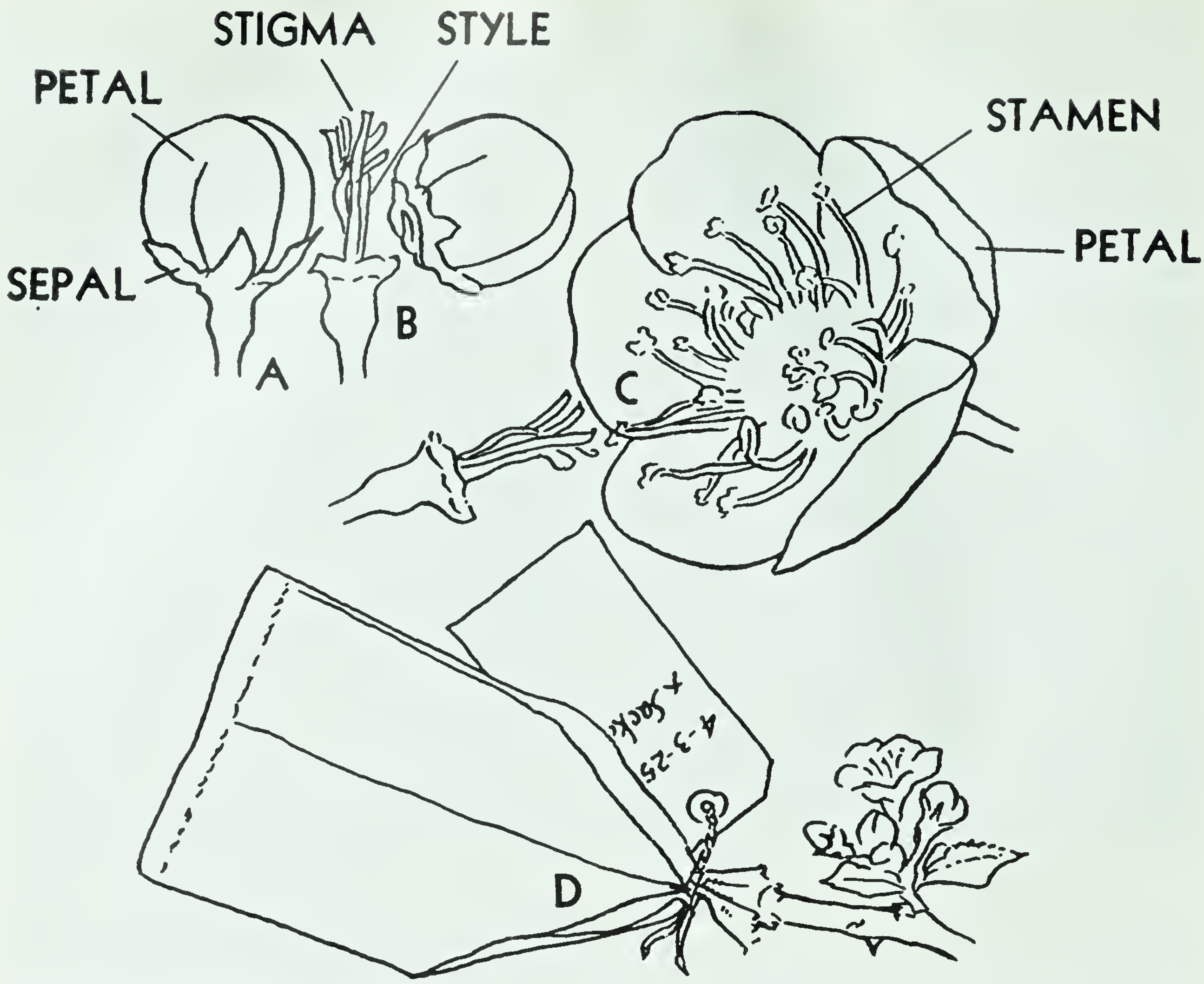


The pistil and stamen are the essential organs of the flower. Some flowers bear both, while other flowers bear only one of these essential reproductive organs.

What are variations? As you know, natural selection is based upon the fact that some individuals are better fitted to survive than are others. These differences in individuals of the same species are called variations. Variations consist of many specific differences in individual traits (qualities or characteristics). For example, garden peas may be tall or short. Their leaves may be smooth or covered with tiny hairs. Their blossoms may vary in color. Their seeds may be smooth or wrinkled, and they may be yellow or green in color. Variations in these specific traits added together make up the differences between individuals.

On what experiments is Mendel's Law based? Gregor Mendel was a European monk who was interested in gardening. He studied garden plants and discovered variations in their appearance. As a result of his observations, he carried on a series of experiments with garden peas.

Mendel knew, as you do, that seeds are formed when pollen from one flower is placed on the pistil of another flower. Pollen is formed in a knoblike anther which grows on the end of a filament. The anther and filament make up



When the bud of an apple or pear is in stage **A**, petals and sepals are removed, as at **B**. All the parts shown at **C** are removed, leaving the pistil. The bag is used to cover the flower after it has been hand-pollinated, as shown at **D**.

the stamen, which is the male part of the flower. The seeds are formed in a space called the ovary, at the base of the pistil, which is the female part of the flower. The pistil has a sticky knob called the stigma, which is supported on a stalk called the style.

When pollen from one flower is put on the pistil of another flower of the same kind, the process is called *crossing*. Mendel crossed tall garden peas—plants about six feet high—with short garden peas—plants about a foot and a half high. When the flowers on these peas were ripe, he carried pollen from the anthers of the tall pea and placed it on the stigma of the flower of the short pea. To prevent other pollen from falling on the stigma, he cut the stamens from the flower of the short pea and kept the flower covered with a bag. In a similar way he pollinated the flowers of tall peas with pollen from the anthers of short peas. In the fall he saved the seeds and kept them through the winter.

When the plants produced by these seeds were mature, the peas were all tall. The shortness of half the parent plants did not appear at all!

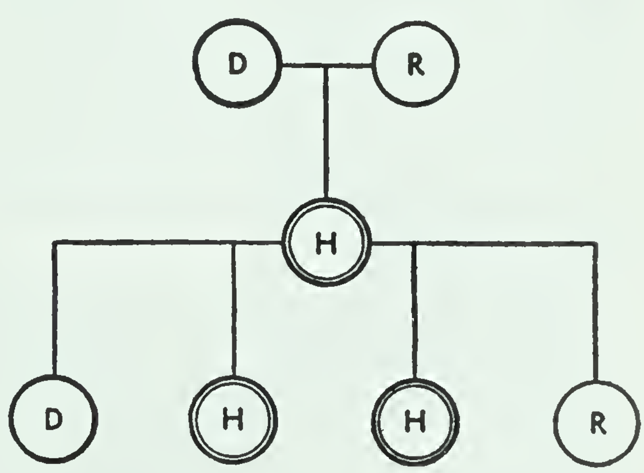
These plants were in turn used in the experiment. Pollen from one tall plant was used to fertilize flowers of other tall plants. In this second generation both short and tall plants appeared. Careful count showed that there were three times as many tall plants as short plants. The shortness trait, in other words, reappeared in one-fourth of all plants produced in the second generation.

In the third generation the short peas were kept separate, and pollen from one short pea was used to fertilize the flower of another short pea. Tall peas were similarly kept separate. The short peas produced only short peas, but the tall peas also continued to produce some short peas.

After the first generation, there were three kinds of peas instead of two. There were some tall peas, which produced only tall peas. These are called pure. Other tall peas produced both tall and short peas. These mixed peas are called *hybrids*. Then there are the short peas, which are always pure because they produce only short peas.

What is Mendel's Law? It is not easy to state Mendel's Law. If you study this diagram, it will make the law simpler to understand. Dominant traits are those which appear more frequently than other traits. Those traits which appear less frequently are called recessive. The law may be stated thus:

1. When individuals having unlike traits are crossed, the offspring of the first generation will be hybrids showing the dominant trait.
2. When hybrids are used for reproduction, three-fourths of the offspring will possess the dominant trait, and one-fourth will possess the recessive trait.
3. All offspring possessing the recessive trait will breed true—that is, will produce only their own kind.



The circles represent individuals with dominant, recessive, and hybrid inheritance. Can you copy this diagram and add another generation to it?

4. The offspring showing the dominant trait include two-thirds which are hybrids, and one-third which are pure dominants.

5. Pure dominants breed true.

The following table gives the results of the experiments which provide the basis for Mendel's Law.

Parents

Tall peas (dominant) Short peas (recessive)

First Generation

All tall peas (hybrids)

Second Generation

Three-fourths tall peas; (mixed—dominant and hybrid) One-fourth short peas (recessive)

Third Generation

Short peas all give short peas (recessive)
Pure tall (1/3) give tall (dominant)
Hybrid tall (2/3) give 3 tall to one short (mixed—dominant and hybrid)

What are some dominant and recessive traits? Dominant and recessive characteristics in other forms of life react in a manner similar to reactions in peas. For example, when a black and a white guinea pig are mated, all of the offspring of the first generation are black; that is, black is dominant and white recessive. In the second generation the pigs follow the same law as peas. There are three black pigs to one white. The white pigs always breed true, but the black prove to be of two kinds: one which always breeds black and another kind which produces black and white in the ratio of three to one.

What is incomplete dominance? As a general rule traits appear according to the law of complete dominance. Yet there are some instances in which the contrasting traits follow the law of incomplete dominance. For example, when red and white four-o'clocks are crossed, we get in the first generation neither red nor white flowers, but instead all are pink. If these pink hybrid flowers are used to pollinate each

Courtesy W. Atlee Burpee Company

These marigold plants are covered with screens to protect them from insects carrying undesirable pollens. The instrument is used to detect odors, for the aim is to produce an odorless plant.

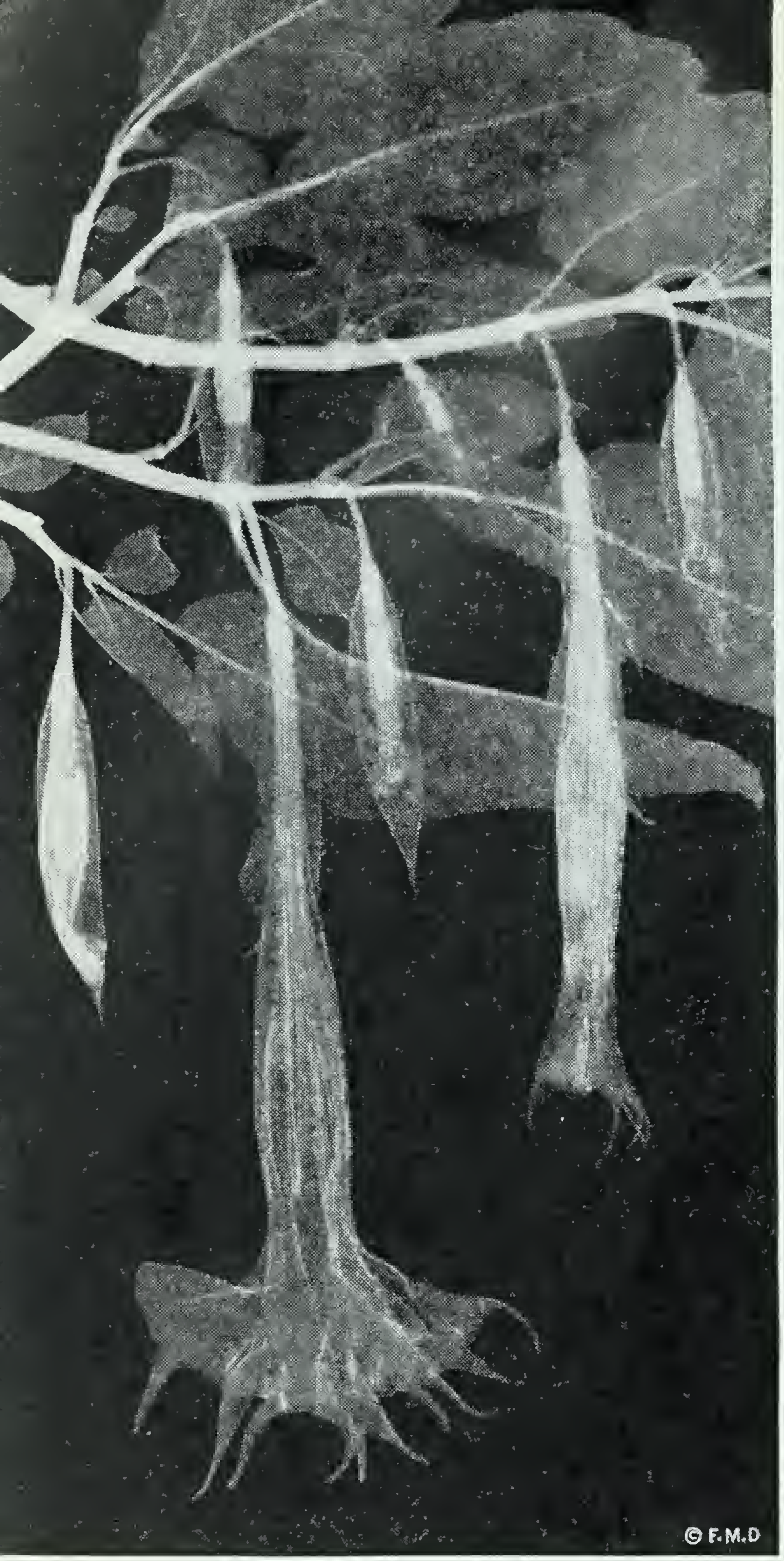
other and the resulting seeds planted, in the second generation colors occur in the definite ratio of one-quarter red, one-half pink, and one-quarter white.

The following table gives a few examples of dominant and recessive traits as determined by actual experiments.

ORGANISM	DOMINANT TRAIT	RECESSIVE TRAIT
Cat	Black	Maltese
Dog	Gray	Black
Cattle	Black	Yellow and red
Horses	Black	Chestnut
Poultry	Black	Yellow
Cotton	Long fiber	Short fiber
Man	Brown eye color Right-handedness	Blue eye color Left-handedness

Filmstrip: Breeds of beef cattle. U.S.D.A.

Exercise. *Complete the following sentences:* Mating two individuals of the same species but possessing different traits is called —1—. The offspring of such a mating is called a —2—. The



Courtesy Francis M. Davis of Santa Monica, Calif.

This X ray of the flower angel's-trumpet shows stages in development of buds into flowers. Note also the veining of the leaves.

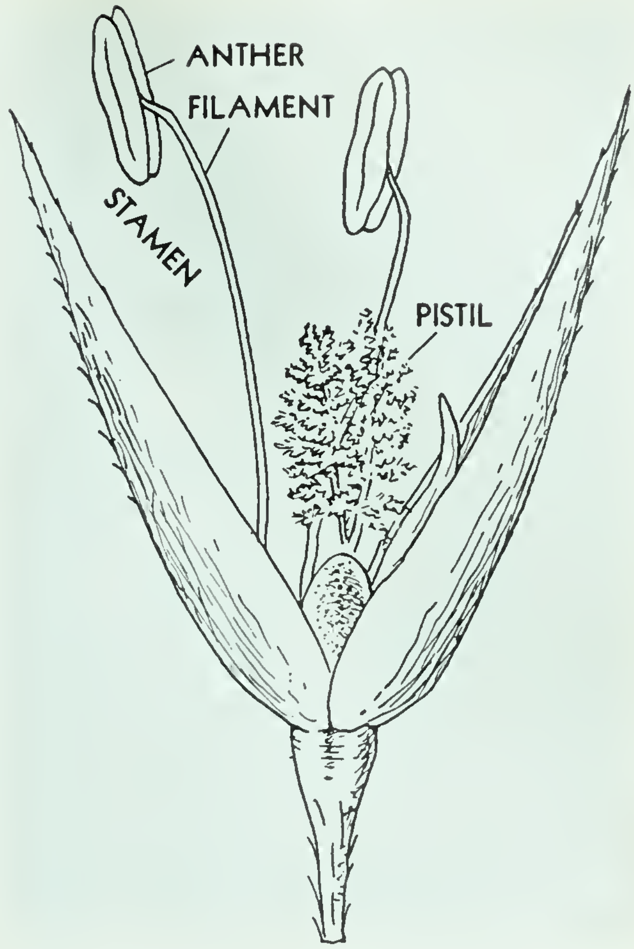
—3— produced by the stamen is placed on the —4— of a second flower in cross-pollination. The seeds develop in the —5—. Hybrids produce offspring, of which —6— resemble the dominant parent, and —7— resemble the —8— parent. Pure dominants breed —9—. The kittens of a pure black cat and a maltese cat would be —10— in color. If these kittens produced young, their color would be —11— and —12— in the proportion of —13—.

4. How does man control plant breeding?

The discovery of the laws which control improvement of plants and animals makes possible many short cuts in producing new or better varieties of plants. Where before it was necessary to discover by experiment and trial and error what results to expect, it is now possible to predict quite accurately in advance what gains can be made from crossing different varieties of plants.

Why is selection of plants important? Out of a field of thousands of plants, there may be only a few that have the qualities which are desired. One plant may be resistant to disease. Another plant may have good yield but may lack other desirable qualities. Before a program of plant breeding (mating and improvement of living things) is started, it is necessary to select the plants which have the traits wanted.

Sometimes no domesticated plant has the desired trait. In such cases it is necessary to find a related wild plant and, by crossbreeding, combine its good qualities with those of the domesticated plant. A plant which will grow in a cold mountain may be crossed with a domesticated plant to make a new variety more resistant to cold than are our common plants.



The essential parts of a grass-flower are the same as those of a showy flower. The leaves are scalelike, however, and because the flower is usually small, its parts are difficult to see.

Can man produce new types of plants? It is possible by crossing to produce plants with entirely new combinations of traits, but so far man has been unable to produce any plant with qualities which do not already exist in other plants. For practical purposes, the plants which are produced are new because they serve new purposes.

New varieties are produced by natural events by a process called *mutation.* The process is not well understood, but it is based upon new arrangements of protoplasm within the cells.

When a cell divides, the nucleus goes through a complex process of rearranging its parts. Inside the cell are tiny, threadlike bodies which are visible when strongly magnified at the time of cell division. Because these bodies absorb dyes when the cell is stained, they are called chromosomes (colored bodies). These chromosomes are the devices which make possible the inheritance of specific traits according to Mendel's Law. When an ordinary cell divides, the chromosomes divide, so that each new cell gets its correct number of chromosomes. These chromosomes vary in number according to the species. The pea plant has 14 and the corn plant 20.

Reproduced from the U. S. D. A. *Yearbook of Agriculture*, 1936

The tassels of corn are the stamen-bearing flowers, the silk the pistil-bearing flowers. The pollen of corn is wind-carried. Can you see an adaptation of the ear to catch pollen?

When reproductive cells are formed, each parent cell loses half its chromosomes, so that each offspring obtains half its chromosomes from each parent.

Sometimes there is some accident at the time of cell division, when the male or female cells form, which changes the number of chromosomes. When this happens, we have a case of mutation—that is, a plant with entirely new characteristics appears. Sometimes these mutant plants die immediately, but sometimes they survive and breed true. Thus a new species is started. There has been discovered a chemical (colchicine) which can be put on flowers to upset the normal division of cells, and mutants are produced more frequently as a result. Use of this chemical is rather recent, and it is not known how many unusual plants may eventually be produced by its application.

How are plants fertilized? As you know, the pollen grain sends a tube of watery protoplasm down the style of the pistil until it reaches the ovule or egg cell in the ovary. The

protoplasm of the pollen grain forms a sperm cell which unites with the egg cell, and these grow as a single cell. When the union is complete, the cell divides, and new cells are formed. The embryo plant is surrounded by a supply of food, and all is enclosed in a skin or covering to form a seed.

How is pollination controlled? Under natural conditions pollen is carried by insects to pollinate showy flowers and by wind to pollinate those flowers which are not showy. The means of controlling fertilization used by Mendel are still in use.

The plant breeder may remove the stamens of the flower to be pollinated and with a brush deposit pollen from another flower on the pistil of the first flower when it is ripe. To prevent pollen from being carried to the flower by a bee or by the wind, the flower is commonly covered with a paper bag. Instead, however, cloth screens may be used.

The grasses produce flowers containing the same essential parts that are found in showy flowers, but instead of having petals and sepals, the flowers of the grasses are enclosed in green, scalelike leaves. The flowers of grasses ordinarily grow in heads, and the individual flower is tiny. If they are magnified 20 times, they are as pretty as the more common flowers. Corn plants produce pollen in the flowers which grow at the top of the stem. These flowers are called tassels. The egg cells are produced in the female flower, which is the silk. The pollen falls upon the silk of the ear, and fertilization takes place in the usual way.

What use is made of the new plants? When seeds are produced by crossbreeding, the process of introducing a new variety is far from complete. Crossbreeding increases the amount of variation in plants tremendously—that is, the offspring have combinations of specific traits different from those of the parents. Because of this, selection must be made with especial care, for a plant that looks good may have in it some definitely undesirable trait. A berry plant may produce large fruit of excellent flavor, growing on a large and vigorous bush, but the fruit may be subject to crushing too easily for practical market use. Such a plant may either be discarded or used for further crossbreeding, depending upon circumstances. Crossing produces a very small pro-

Courtesy U. S. Department of Agriculture

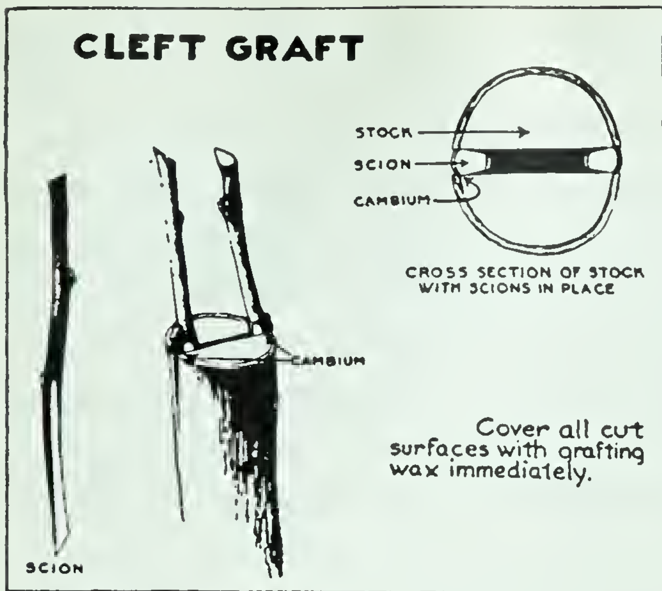
The strawberry plant is capable of propagating itself by means of runners. As the new plant formed becomes well rooted, it is capable of carrying on its existence independently.

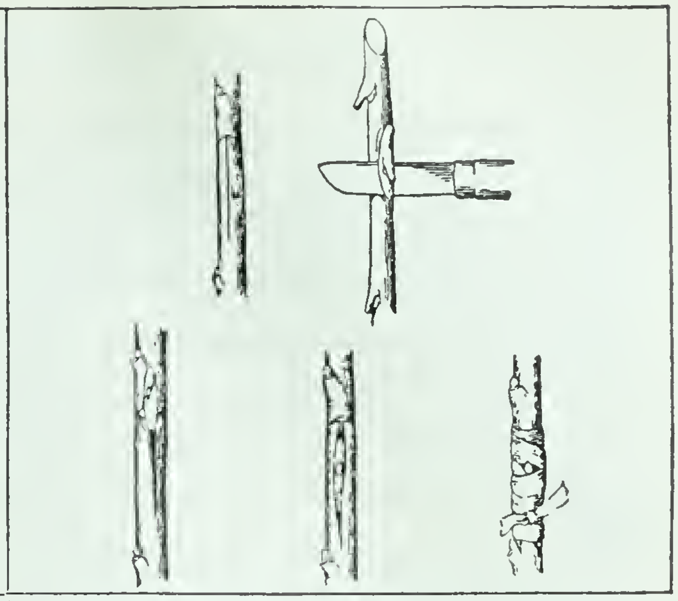
portion of useful plants. For example, in one series of breeding experiments carried out in Maryland, 86,000 strawberry seedlings were raised, but of these only seven wer : of such desirable qualities that they were saved and named.

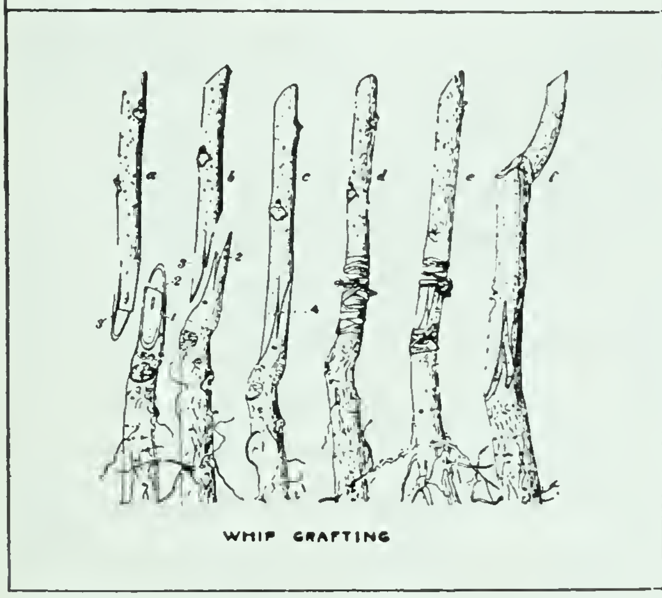
If a plant seems to have every desirable characteristic which the plant breeder is seeking, he then keeps it and very carefully observes its development. If it is a plant, such as wheat or corn, which is always produced from seed, the seed must be planted until enough is produced to put it on the market. It must also be watched to observe whether or not it will breed true and whether or not it has hidden but undesirable traits.

If the plant is one which is produced by means other than by seeds, enough plants must be produced to establish the new variety in quantities sufficient for marketing. It is expensive both to produce new plants and to advertise them to sell them for a profit. Not many farmers are willing to risk their year's income by planting or growing crops which have not been proved in quality.

How are plants produced when not grown from seeds? There are two ways of growing plants without use of seeds. One is to cause roots to grow from the stem of a desirable plant. The other is to join the stem of a desirable plant on roots of a less desirable plant.







Courtesy U. S. Department of Agriculture

The two methods of grafting (*left*) and the method of budding (*above*) are the chief means of propagating fruit trees. The inserted branch or bud is taken from a tree known to bear good fruit. If you wish to experiment with grafting, practice with twigs and branches of worthless trees until you become skillful. Grafting should be done before sap flows in the spring.

Strawberry plants send out a stem from the parent plant. This stem, called a runner, puts forth roots and leaves where a joint touches the ground. Each joint eventually becomes a separate plant. You know how to make softwood cuttings. Hardwood cuttings are made by planting sections of stems without leaves. They are rooted in much the same way as are softwood cuttings. Grapes and currants may be started from hardwood cuttings.

When a stem is buried while it is still attached to the plant, the process is called layering. New roots and branches appear at joints, and these new plants may be separated from the parent plant as soon as they are large enough and planted elsewhere. Raspberries and grapes may be started by layering.

The eyes of potatoes are buds, containing in undeveloped form both stem and leaves. When the eye is planted, it draws upon the supply of food in the potato until it gets a start and then develops roots from the stem.

It is possible to join a branch of one tree upon the stem of another in such a way that the branch will grow. This process is called grafting. Just inside the bark is the cambium layer. The cambium layers of the two stems must join. The simpler kind of grafting is accomplished by cutting off the stem of a tree and cutting a V-shaped notch in it. The branch is cut in the form of a wedge, and the two are carefully fitted together. Then the graft is wrapped with string and covered with wax to keep out decay. A more complex graft is called whip graftage, shown in the diagram on page 659.

A bud from one tree may be cut off and slipped into a T-shaped cut in the bark of another tree, and the bud will grow into a branch. This process is called budding.

All these methods of propagating or producing plants are used when the seeds of the parent plants will not breed true. Most of our fruits, potatoes, and many flowering shrubs do not produce offspring like the parents from seeds. They can be produced only by one of the methods described.

The roots of European grapes cannot survive the parasites found in this country, and as a result such grapes are grafted onto the roots of wild grapevines. Another advantage of grafting is that more than one kind of fruit can be grown upon one tree. Several kinds of apples and pears will grow on a tree. Cherries and plums will grow upon the same tree. But the fruits must be similar in structure, or grafts will not thrive on one tree.

Filmstrips: Selection and care of seed corn. U.S.D.A.
Grafting and budding fruit trees. U.S.D.A.

Exercise. *Complete the following sentences:* The essential parts of a flower are the —1— and —2—. The colored, threadlike bodies in the cell nucleus are the —3—. These divide when the —4— divides. The —5— cells have only half as many of these as do other cells. The mating and improvement of living things is called —6—. Causing a branch of one plant to grow on the stem of another is called —7—. Strawberries reproduce by means of —8—. Union of egg and sperm cells is called —9—. Potatoes are grown from —10— called eyes.

Science activity. Make a model of a flower, showing details of the ovary, using soap or a candle, wires, and cardboard.

5. How does man control animal breeding?

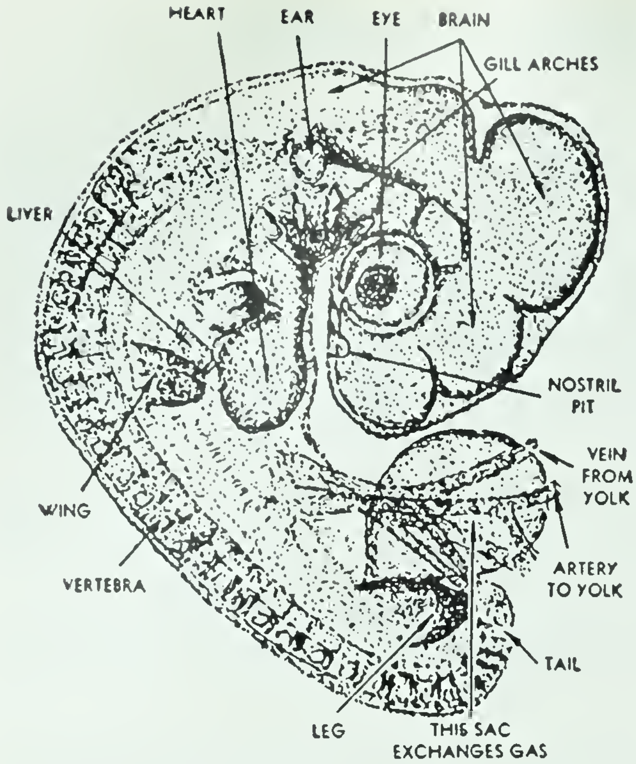
The problems of the animal breeder are considerably different and in some ways more difficult than are those of the plant breeder. Our domestic animals in general reproduce slowly and produce few offspring compared to plants. First-quality farm animals are quite expensive, so that many farmers can scarcely afford the money required to invest in a herd of good animals.

But otherwise the problems are about the same. It is necessary to select animals with the desired characteristics and mate them to keep these traits or, by crossbreeding, to try to bring about more desirable combinations of traits already existing.

How do animals reproduce? As you know, farm animals are either birds or mammals. They are alike in that fertilization takes place in the reproductive organs of the female. The male produces sperm cells in organs called testes. The female produces egg cells in the ovary. When mating occurs, sperm cells are deposited by the male in a tube leading into the female's reproductive organs, and the egg and sperm cell unite. As soon as the mammal egg is fertilized, it produces around itself a thin membrane and attaches itself to the wall of the uterus—the organ in which development takes place.

The embryo takes its food from the mother by absorbing it from her blood stream. The blood stream of the embryo is not connected directly to the blood stream of the mother, but both are in contact with a membrane which separates them. The kind and amount of food available to the mother determines to a considerable extent the growth and health of the offspring. Thus it is important that animal breeders care for the female animals as perfectly as possible.

Female birds may lay eggs without mating, but the eggs are infertile—that is, they will not hatch. When enough fertile eggs are laid, the female bird sits upon the nest until they hatch. The usual number of eggs hatched by hens or ducks ranges from 10 to 15. Modern hatcheries do not employ hens for producing chicks, but instead put the eggs into incubators. The incubator is a box heated by electric coils or a lamp. The temperature is controlled by a thermostat,



A chick embryo in an egg looks like this after four days of growth. It is not quite a third of an inch in length. The fully formed chick leaves the shell after 21 days of growth.

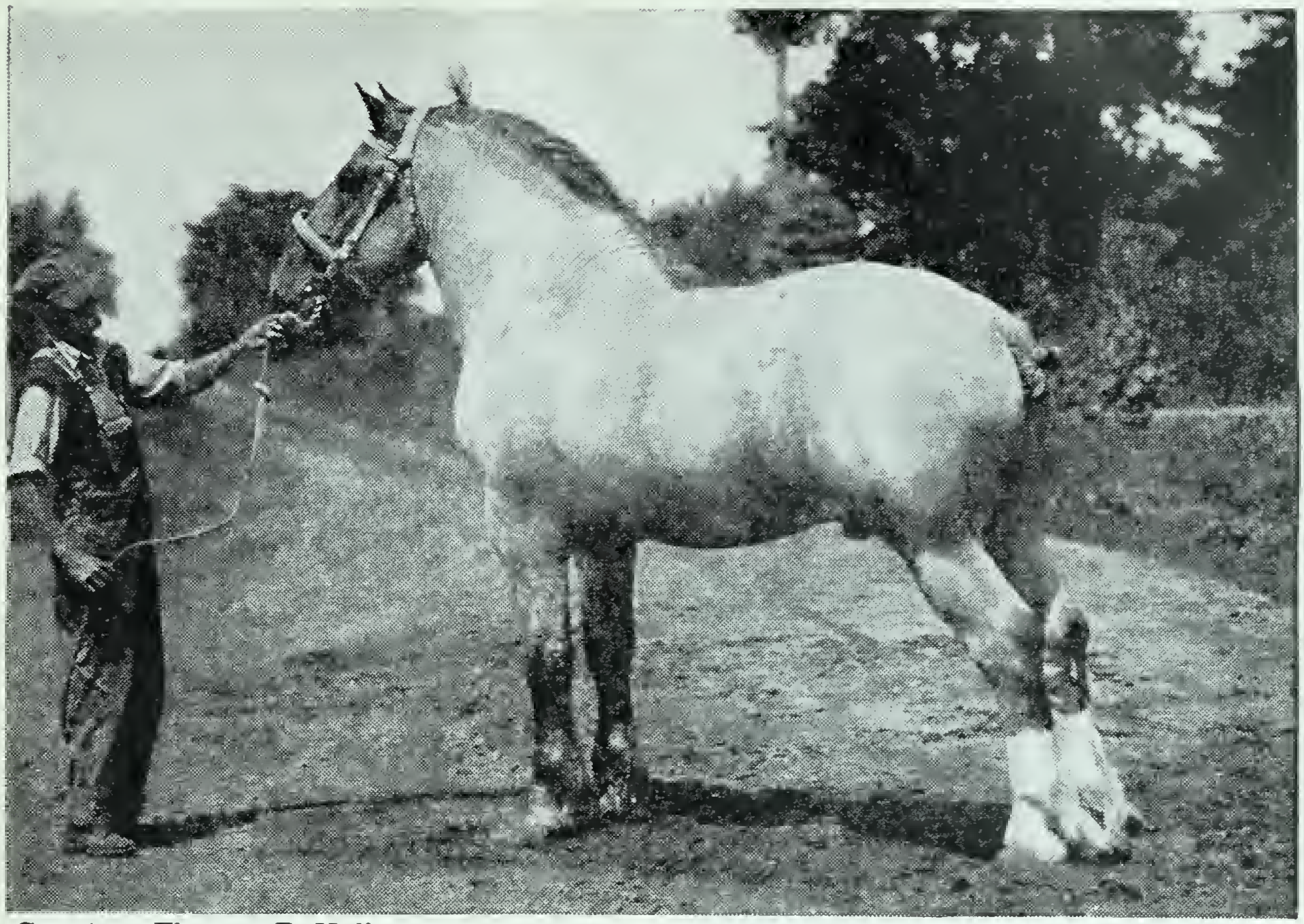
and the humidity is carefully regulated. The eggs must be turned daily to insure perfect development of the chick.

The chick develops from a single cell attached to the yolk of the egg. A system of blood vessels spreads through the yolk, and a tiny heart circulates blood to collect food from the egg and to get rid of gaseous wastes. A sac develops for the exchange of gases. Gradually budlike wings and legs appear, and the head becomes definitely recognizable. From this stage onward the embryo looks more and more like a chick, until at the end of 21 days the chick breaks its way from the shell. The chick has a horny knob on the top of its beak for breaking through the shell.

What animals are commonly produced on farms? Practically all farmers who have cattle produce the calves on the farm. A calf may be used for veal at the end of six weeks, for baby beef at the end of six months, and for beef at the end of a year. A young cow ordinarily should bear her first calf at the age of 2 or 2½ years. A cow, of course, does not give milk until she has produced a calf, and a dairy cow continues to produce milk for 10 to 11 months after the birth of the calf. A beef cow gives milk enough for her calf and little, if any, more.

The usual farmer has only two or three horses and may not find it profitable to produce colts. There are large horse-breeding farms which produce horses for sale to farmers and to those who wish to own saddle horses.

The ordinary male horses used for drawing wagons and for saddle use are not capable of reproducing because they have been operated upon to remove the testes. Steers and



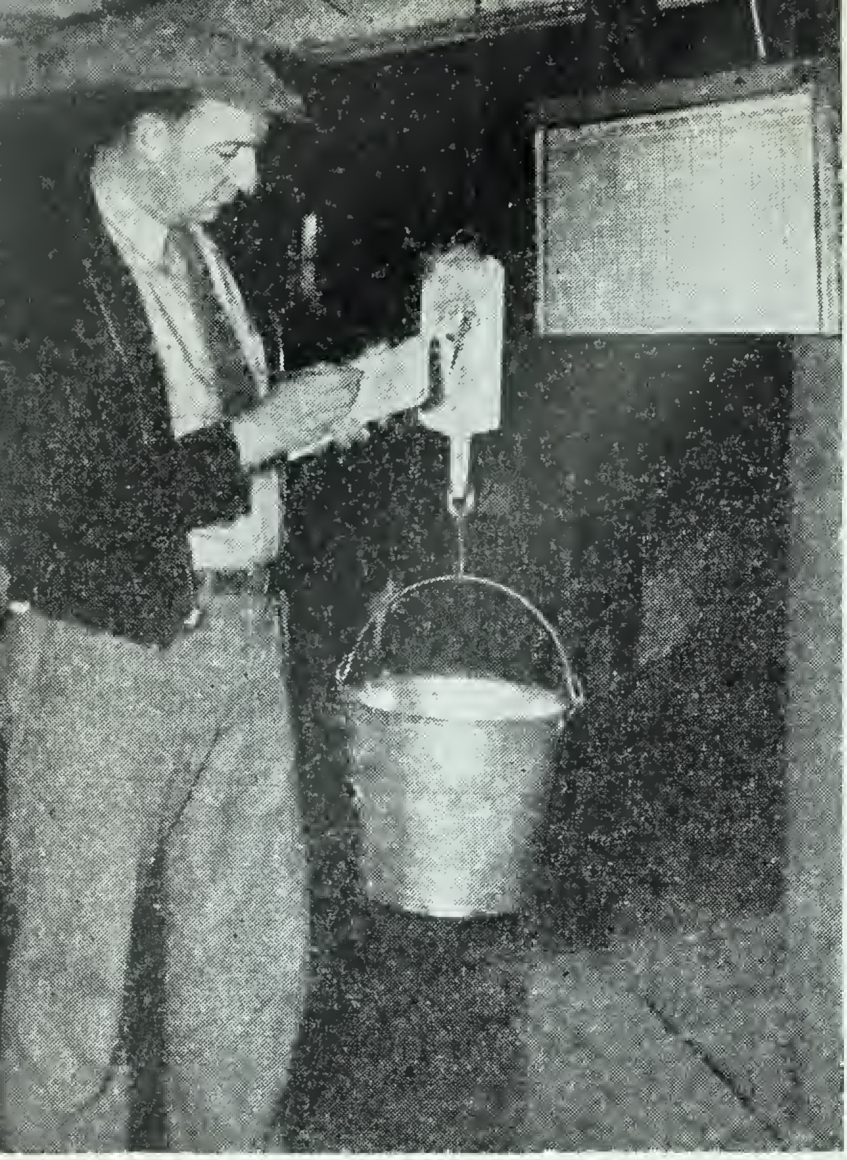
Courtesy Thomas R. Holbert

The Belgian breed of horses is one of the best draft breeds. Note the sturdy body, neck, and legs of this prize-winning stallion.

farm male pigs that are raised for meat similarly are not able to reproduce. The stallion, the bull, and the boar are likely to be vicious and difficult to handle. The meat of bulls and boars is tough and strong.

The following table includes the correct names of the different animals used for producing young on the farm and the amount of time required for the young to develop. The period of gestation is the length of time the young animal develops within the mother's body; the period of incubation is the amount of time the eggs require to hatch.

NAME OF MALE	NAME OF FEMALE	NAME OF YOUNG	PERIOD OF GESTATION OR INCUBATION
Bull	Cow	Calf	280 days
Stallion	Mare	Colt	330 days
Ram	Ewe	Lamb	145 days
Boar	Sow	Pig	115 days
Rooster	Hen	Chick	21 days
Drake	Duck	Duckling	28 days



Courtesy *Minneapolis Tribune*

The scales is the instrument needed to select a champion cow. This cow, Femco Alma, produced 12.5 pounds of milk in six hours. Registered cows are given names, and no other cow may be registered under the same name.

Why is the sire so important? Purebred livestock—that is, animals which are of proved quality and of a certain variety—are expensive. The average farmer has scrub livestock—animals which are of poor quality and of mixed ancestry. To improve a farm herd by selling the scrub animals and replacing them with purebreds would cost thousands of dollars.

But instead of buying a whole herd, the farmer can buy a male animal—the sire—and produce offspring which have one purebred parent. One male mammal may produce 20 to 150 young a year, while one female can produce few young. Thus it is easily seen that the male becomes many times more important in improving the quality of the herd than any female animal can be.

If a farmer continues to use only purebred sires, he can gradually improve the quality of his herd until, for practical purposes, the animals are purebreds. The second generation of offspring will have three-quarters purebred qualities, the third generation seven-eighths purebred qualities, and the fourth generation fifteen-sixteenths purebred qualities. With cattle, this program will require a minimum of eight years; but with sheep, pigs, and chickens, it can be brought about in four years.

Are there hybrid farm animals? In general, crossbreeding is not considered a wise practice on the farm, except as already described to improve the quality of scrub herds. If a purebred Holstein dairy cow is crossed with a purebred

Courtesy U. S. Department of Agriculture

While the beef animal at the right is no champion, it is far superior to the scrub at the left. The improved animal has a deeper, broader body than the other.

Shorthorn bull, the calf is not likely to have the desirable qualities of either parent. Livestock breeders are very careful to avoid crossbreeding in order to be sure of the quality of their livestock.

The mule is the only farm animal that is always a hybrid. The father of the mule is a jackass, a kind of donkey, and the mother a mare. The mule is not fertile—that is, it cannot produce colts—probably because the ass and the horse have differing numbers of chromosomes.

How are desirable animals selected? The test of a farm animal is its ability to produce. To select producing animals, various methods are used. In a flock of chickens some hens lay many more eggs than do others. The best way to separate these hens is to use trap nests in which the hen lays her egg. Each hen has a numbered leg band. When the hen is released from the nest, the attendant makes a check mark after her number. Hens which are not laying are thus easily detected. Hens can also be sorted out or culled by examining their body build. A poor layer has a poorly developed body. In one experiment with 75 flocks of hens, 4419 hens were chosen to be kept, and 3137 were to be rejected. Those which were to be kept in a test laid on the average 2018 eggs a day, while those which were to be rejected laid only 112 eggs a day.

There are two important tests of a dairy cow: the weight

of milk given per day and the per cent of butterfat it contains. Then too, some cows give milk for a longer time than do others given the same care. The only way to measure the value of a bull in a dairy herd is to compare the milk-giving abilities of his daughters with the abilities of their mothers. If the average yield of the daughters is considerably in excess of the mothers, the bull has contributed something of value to the herd. A bull which looks very good in the show ring may be of little value in herd improvement.

Pigs and beef cattle are judged by their ability to put on meat in proportion to the amount of food they eat. Horses are judged either by their speed in running or their strength in pulling. In the case of pigs, it is important to keep sows which produce large litters of pigs—10 or more being desirable.

Filmstrip: Better sires—Better stock. U.S.D.A.

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* sperm, egg, gestation, stallion, sire, testes, ovary, selection, hybrid, mare, purebred, mule, improvement.

6. How have farm crops and animals been improved?

Because of the careful work of the plant and animal breeders, it is possible for the intelligent farmer today to select a crop or animal fitted to almost any kind of soil or climate at all fit for agriculture. Instead, too many farmers follow the easiest course and use crops and animals which cannot possibly yield them a profit.

What kinds of cattle are grown for beef? There are two chief beef breeds of cattle grown in the United States: the Herefords and the Shorthorns. The Herefords have white faces and red bodies. Shorthorns are deep red, roan, or white. Each has the ability to produce large quantities of first-quality beef. The Herefords are somewhat more able to find food in barren pastures. The Shorthorns are somewhat better milk producers than the Herefords.

Beef cattle can be grown profitably on any farm where pasture and hay are available. They can also be grown

where there is range—open areas of grass and uncultivated land. Range-fed cattle need hay in winter and are usually put into rich pasture or fed corn and hay to fatten them for market.

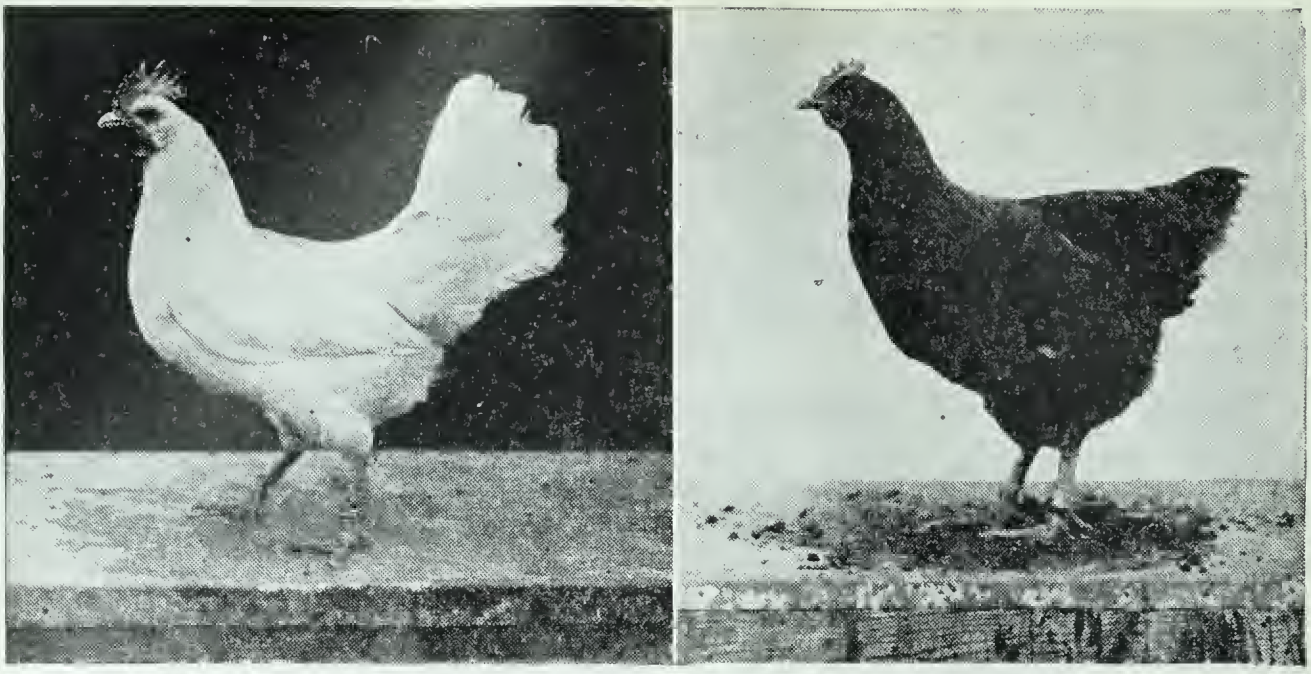
Courtesy Wyoming Hereford Ranch

This Hereford bull is typical of the best animals of his breed. Such a sire would bring up the meat production of a scrub herd to a marked degree.

What kinds of cattle are grown for milk? The Holstein is the outstanding dairy cow. It is a large, black-and-white cow, and is rugged and strong. Holsteins give more milk than any other breed of cattle, but the milk is not particularly rich. Yet in spite of the lack of richness of their milk, Holsteins produce more butterfat than do other breeds because of the large amount of milk they give.

Jersey and Guernsey cattle are somewhat similar in appearance. Jerseys are smaller and fawn colored; while Guernseys are sometimes red and white in color, although the usual color is a golden brown. Both breeds are producers of rich milk. The milk of Jerseys is somewhat richer, while that of Guernseys is more abundant. The total yield of butterfat of Guernseys is somewhat above that of Jerseys. There are several other breeds of dairy cattle found in certain localities, the more common being Brown Swiss and Ayrshire.

The average scrub cow produces only about 200 pounds of butterfat per year. Some of the best purebreds produce more than 1000 pounds per year. In a study of 554 cows of 36 dairy herds it was found that the butterfat production of the best one-fourth of the cattle was double that of the worst one-fourth. Good judges believe that in the entire country one-fourth of the cows kept for milk do not pay for their cost of keeping, and nearly a fourth more fail to yield an annual profit. By use of culling of the worst cows, and by using only purebred bulls for breeding, the national yield of butterfat per cow could probably be doubled in 10 or 15 years.



Courtesy U. S. Department of Agriculture

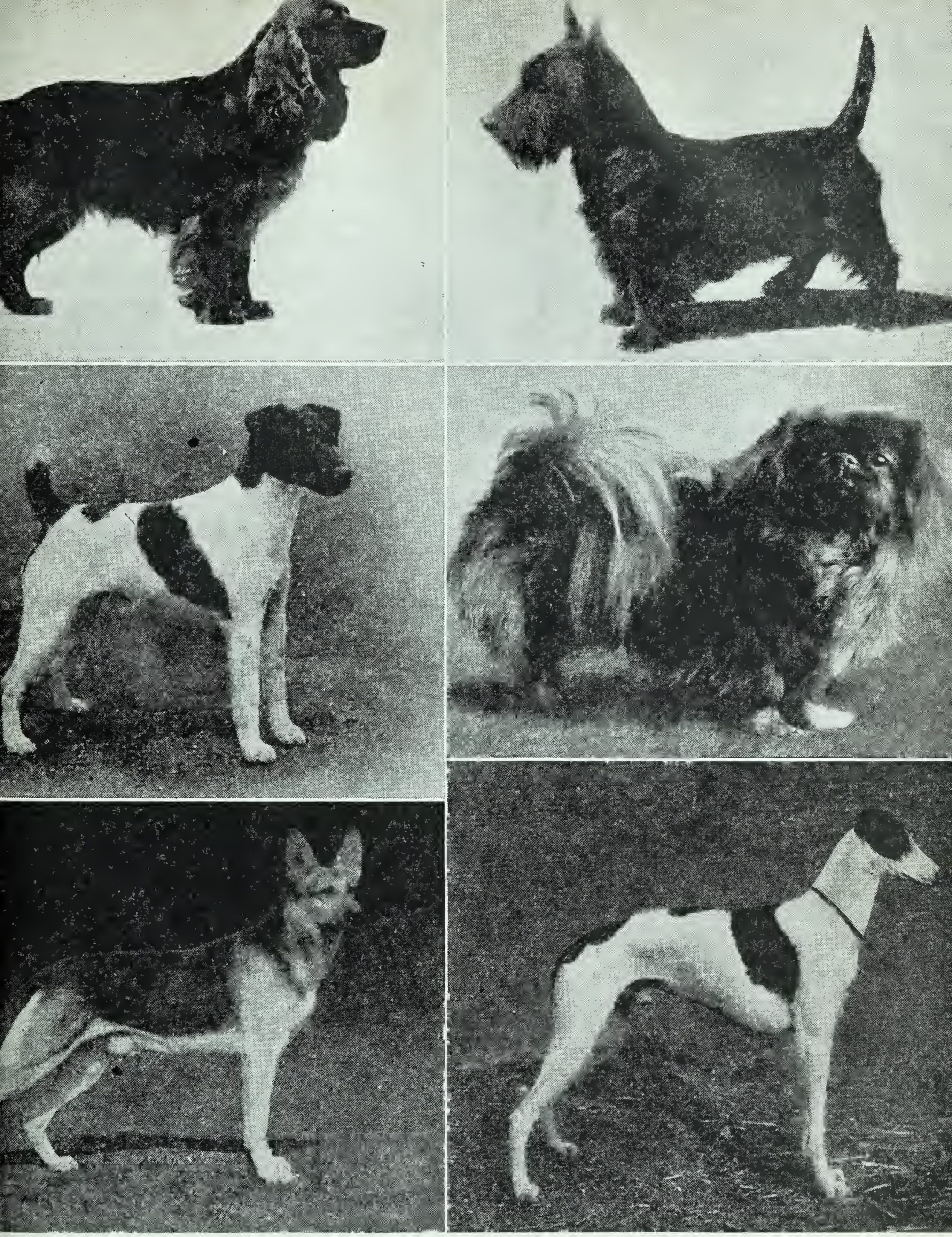
The best index of the breeding worth of a hen is the kind of offspring she produces. This White Leghorn (*left*) laid 290 eggs and had seven daughters that laid an average of 230 each. The Rhode Island Red laid 236 eggs and had five daughters that laid an average of 226 each.

Dairy cattle need good care to produce milk. Good pasture, hay containing protein, some grain, and an abundant supply of fresh water are essential for producing milk. Ensilage in winter takes the place of green feed in providing certain vitamins.

What are the common breeds of horses? The typical farm horse is a scrub. These scrub horses can be improved by breeding mares to stallions of one of the good draft breeds. The three leading draft breeds are the Belgians, Clydesdales, and Percherons. These draft horses vary in color and minor details, but all are huge, deep-chested, short-legged, and powerful. Their feet are broad and strong. Their necks are thick and arched.

There are few saddle horses used on farms today. In the West they are used on stock and dude ranches, and in the rest of the country for display and pleasure. The hunter is a sturdier horse with more powerful muscles, necessary for jumping. Saddle horses are slender and small-boned. Their legs are long and their hoofs small.

Ponies are small horses, the best known being the Shetland pony on which children ride in amusement parks. These ponies are chiefly used for children's pets in this coun-



Courtesy M. Kettel, Geneva, Wisconsin

Among no other domesticated animal is there a greater variety of sizes and shapes than there is among dogs. Every breed of dog has its peculiar traits which make it different from others. At the top, the cocker spaniel (*left*) and the Scottish terrier; in the center, the fox terrier (*left*) and the Pekingese; and at the bottom, the German shepherd dog (*left*) and the greyhound.

try, although in Europe they are used for drawing carts to haul loads.

What are the best breeds of poultry? There are dozens of kinds of poultry, ranging in size from the Bantams to the Cochins. The best egg breed, however, is the White Leghorn. This is the nervous slender chicken used for producing eggs in commercial plants. The White Leghorn that does not produce 200 eggs a year if given proper care is not a good example of her breed. There are other chickens that may be of more value on farms, however, for many breeds are large enough to provide meat as well as eggs. Since half the chickens are roosters, they represent a loss if they cannot be eaten or sold for meat at a profit. Two standard breeds of general-purpose chickens are Rhode Island Reds and Barred Rocks.

The record egg production about 30 years ago was 251 eggs a year, but now it is 358 eggs per year. One duck laid 369 eggs in a year, or four more than one a day. Yet the average egg production per hen, per year, in flocks in this country is about 100 eggs. Many hens do not earn the feed they eat.

How do breeds of dogs differ? While most dogs have almost no practical value, they are commonly desired for pets. No other animal illustrates better the possibilities of selection and breeding for producing different varieties than do dogs. Some dogs are selected for hunting and pointing game, some are selected for ability to learn to herd sheep, some are selected because they can fight, and others because they are strong enough to pull sleds. The Seeing-Eye dog is trained to guide the blind. There is a special school in Morristown, N. J., for training these dogs.

In all, there are about 200 different breeds of dogs, and they range in weight from little more than a pound to about 300 pounds.

How are farm crops improved? Crops serve special needs, as do animals. Corn used for table consumption is fine-textured and sweet. Field corn produces several large ears to the stalk. Popcorn has a tough skin covering the grain to hold steam until enough pressure is built up to explode the cells. Then too, corn is grown for special uses. For making

cornstarch, a kernel rich in starch is needed. For feeding cattle, one containing much protein is desired. For making corn oil, a kernel rich in oil is required. It was found possible to increase the oil content from 4.7 per cent to 7.3 per cent by selection for oil yield. Corn is also developed to mature at a certain date, to grow best at a certain night temperature, and to resist frost.

Reproduced from the U.S.D.A. *Yearbook of Agriculture,* 1937

Cultivated blueberries are as large as grapes. The largest berry on this bush was a little more than an inch in diameter.

It is possible to develop disease-resistant crops. Near Chicago, cabbage fields became infested with a disease known as the yellows. In one 15-acre field all but two plants died of the disease. But these two were kept for seed, and from them was developed a variety resistant to the disease. The cabbage industry was thus saved from ruin. If the resistant variety of plant has undesirable traits, they usually can be eliminated by crossbreeding until a resistant plant with desirable traits is produced.

Farmers should learn to select seed carefully. Merely by selecting seed corn carefully, yield was increased five bushels per acre. By selecting the corn on the stalk to judge the quality of all ears on the stalk, yield was further increased two bushels. Potatoes should be selected by the hill—the entire yield of a plant—rather than by picking individual potatoes from a bin, for a large potato may be the only one produced by a given plant.

Are plants still being domesticated? Constant attempts are being made to find new varieties of plants for both cross-

Courtesy J. I. Case Company

Cultivation of corn frees it from the competition of weeds, conserves the soil moisture by loosening the soil, and permits rain to soak in rapidly.

breeding and for domestication. The wild blueberry is small and seedy, but in a series of experiments begun in 1906 a domesticated variety was started, and now several varieties are available. Some are now more than an inch in diameter. However, since blueberries require an acid soil, their cultivation probably will not become general all over the country.

Wild potato plants have been located in various parts of Central and South America to use for crossing with domestic plants to increase resistance to drought and disease.

Filmstrips: Soybeans: Culture and uses. U.S.D.A.
Breeds of swine. U.S.D.A.

Exercise. *Make a table by ruling your paper into three columns. Head the columns as follows:* BREED OR VARIETY, SPECIAL CHARACTERISTICS, SPECIAL VALUE. *Complete the table by writing in information about plants and animals grown on farms. If possible find information about animals not mentioned in this problem to fill in part of the table.*

7. How does good care improve crops and animals?

The successful farmer selects crops and animals with good heredity and gives them good care. Both are important. The best care will not make a cow give large amounts of milk if she has not inherited that ability. Nor will the best cow give large quantities of milk if she is given poor care.

Agricultural experts estimate that the annual yield of corn in this country is decreased about one-third through failure to control such factors as poor seed, weeds, insects, plant diseases, and lack of sufficient moisture in the soil dur-

ing the midsummer. The farmer can control these factors by proper selection of seed, rotation of crops, preparation of soil, and proper tilling of the land while the crops are growing.

Farm work consists of growing plants and animals. These two activities are often closely related because many of the plants raised are used to feed animals. The farmer controls the growth of crops chiefly by the things he does to the soil.

How is the soil prepared? There are about a dozen elements in the soil that plants require. Most of these elements are present in the soil in such large quantities that they will last for many years. But nitrogen, phosphorus, and potassium often need to be replaced. Farmers formerly took no thought of replacing these elements in the soil. Progressive farmers now realize that they must fertilize the soil to put back those elements that their crops have withdrawn. Cattle provide manure which adds nitrogen, phosphorus, and some potassium to the land. Legumes add nitrogen to the soil. Still another way to enrich the soil is to add commercial fertilizers.

Plowing the soil serves several purposes. It loosens the soil so that the roots of seedlings can grow easily. When the delicate roots first appear, they are not able to force their way through hard-packed soil. Plowing also mixes air with the soil. The roots of plants must have air in order to grow. Heavy, clayey soils are especially in need of air.

Plowing in the fall has several advantages. More time is given for the decay of humus which has been turned under, thus increasing the supply of available minerals. It exposes the soil to the effects of frost, which helps to break it up into smaller particles. Fall plowing also helps to control certain insects that live in the soil, because they are exposed to birds and unfavorable weather conditions.

What is rotation of crops? Many farmers practice rotation of crops. This rotation may include three or four different crops which are planted in turn on successive years. A common three-year rotation is clover, wheat, and corn. In the southern states it may be clover, cotton, and corn. A four-or-five-year rotation may be used. The best rotation usually includes some legume, such as clover or alfalfa.

Courtesy U. S. Department of Agriculture

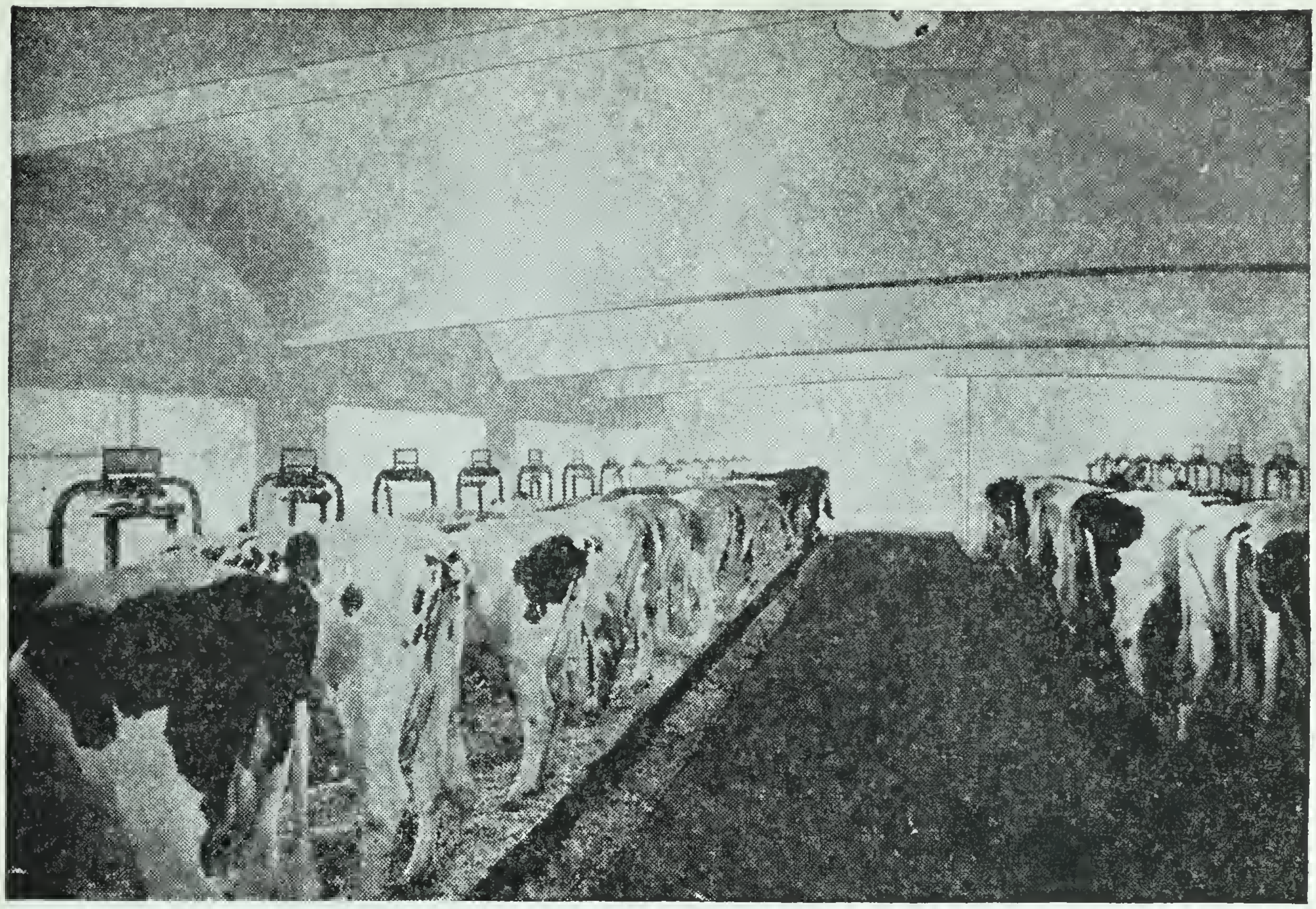
These people are picking beans. Beans not only provide a valuable food but work into crop rotation plans well. They provide nitrogen to the soil and permit it to be cultivated.

Experiments have shown that rotation of crops increases the yield. One experiment was carried on over a period of 30 years. One field was planted continuously to corn. The average yield was 34 bushels per acre. In another field a three-year rotation of corn, oats, and clover was practiced. In this field the average yield of corn was 50 bushels per acre, a noticeable increase.

Rotation of crops offers several advantages. It enriches soil by use of legumes. Rotation helps to control insects, for an insect that attacks one crop may not attack another and may be starved out in a field. Plant diseases are similarly controlled to some extent. The use of a cultivated crop in the rotation series makes possible the killing of weeds. If a field of wheat is badly infested with weeds, there is planted the next year some crop, such as corn, that can be cultivated. If a pasture crop is included in the rotation, the hoofs of animals pack the soil, and their manure enriches it.

And still another advantage of rotation of crops is that it enables the farmer to raise crops which will allow him to distribute his time economically through the growing season. One kind of crop may require special care at one time of the year, another crop at another time. For example, wheat and corn are planted at different times and they are harvested at different times. They make a good combination because they distribute the needed work during different months.

What protection from weeds do plants need? It is important that crops should be protected from weeds if they are to yield large returns. In one experiment the average yield in a properly cultivated corn field was 40 bushels per acre. In a similar but uncultivated field it was less than a half a bushel per acre. The weeds destroyed practically the entire uncultivated crop.



Courtesy Lone Star Cement Co.

A modern barn is well lighted and warm. It is also clean. Cows given good care actually produce more milk than do cows left outdoors or in cold barns.

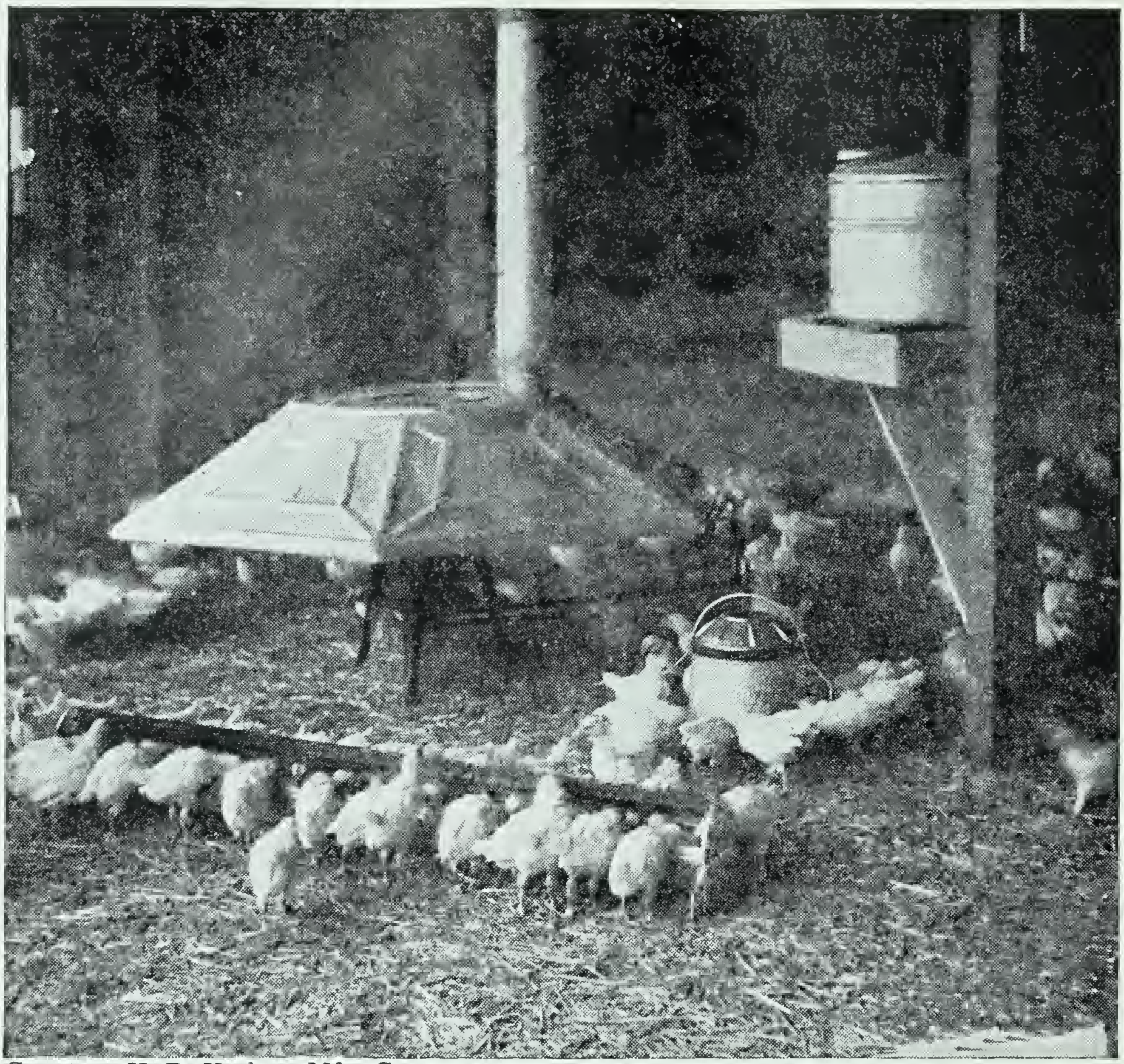
Weeds can be controlled by cultivation in such crops as corn and potatoes that are grown in rows. This cultivation kills the weeds that have already started to grow and leaves a surface mulch that is so loose and dry that the conditions are unfavorable for the germination of weed seeds. Weeds rob the crops of light, water, and minerals.

Cultivation mixes air with the soil and leaves it in good condition to absorb rain.

To prevent introducing new weeds, some states require by law that anyone who sells certain farm seeds must have them tested for weed seeds. The bag must bear a tag giving the kinds and per cent of weed seeds present. Thus the farmer knows what he is buying.

What care do animals need? The three most essential things needed in the care of animals are food, water, and shelter.

Animals need a balanced ration, just as people do. They need three kinds of nutrients: proteins, fats, and carbohydrates. Good sources of protein for cattle are alfalfa,



Courtesy H. D. Hudson Mfg. Co.

Young chickens require warmth, which is provided by the stove; food and water, which are kept before them in containers; exercise, which is provided by the litter; and the light to see by.

clover, and mill feeds, such as bran and cottonseed meal. Sources of fats and carbohydrates are corn, corn fodder, and barley. The best proportion for dairy cattle for milk production is about five or six pounds of fats and carbohydrates to one pound of protein.

Cows also need green food. In summer this is provided by pasture grasses. In winter it is provided by silage.

Not only should the ration be balanced, but there should be a variety of foods. Cattle, like people, enjoy a variety of foods. The more food a cow will eat and digest, the more milk she can give.

An average dairy cow drinks about 15 gallons of water

daily. This water should be warm. Dairymen often place heaters in the tanks during the winter to take the chill off the water. Water is essential for production of milk.

Dairy cattle need a regular supply of salt. It may be sprinkled on their feed or kept in cubes in a yard or pasture. Cows give more milk if properly sheltered than if left outdoors in cold weather. The barns should be well ventilated and provided with plenty of light.

What care do chickens need? Nowhere is the effect of proper care better shown than with chickens. Because eggs are highest in price during the winter, this is the most profitable time for hens to lay.

Chickens should be given five types of food: dry mash, scratch feed, animal feed, green feed, and mineral feed. A dry mash may be made of corn meal, bran middlings, and ground oats. Scratch feeds include such grains as oats, wheat, or corn. In order to give the chickens the exercise they need to keep them healthy, grain is thrown among straw or litter where the chickens must scratch to get it. Animal feed is very important for egg production, since it is rich in protein. It is provided in meat scraps, skim milk, or buttermilk. During the winter, green food is provided by feeding mangels, sprouted oats, cabbage, and alfalfa leaves. Mineral feed is especially necessary for making the shell of the egg. It is provided in grit, oyster shells, and ground bone.

For high egg production it is especially important in the colder northern states that chickens should be provided with a warm, dry, sunny shelter during the winter.

Filmstrips: Farm manures. U.S.D.A.
Raising domestic rabbits. U.S.D.A.

Exercise. *Complete the following sentences:* Growing different crops in succeeding years on the same area is called —1— of crops. The value of a legume crop is that it adds —2— salts to the soil. One advantage of plowing under turf is that it adds —3— to the soil. Weeds are a common cause of a —4— in yield of crops. One of the best ways to kill weeds is to —5— the soil. Rotation of crops helps to control —6— pests and plant —7—. Air is introduced into the soil by —8—. Green foods for winter may be fermented in a —9—. Alfalfa and clover are good sources of —10— for cattle. Chickens need —11— to make eggshells.

Science activity. Visit the best farm in your community, and write a complete report on the reasons it is best. Also, see whether you notice chance for still more improvement. Your county agent will help with information. If you live in a city, visit a greenhouse instead.

8. How can plant diseases be controlled?

Practically all the crops that man raises—whether fruits, vegetables, or grains—are attacked by various kinds of fungi. Almost any part of the plant may be attacked—the leaves, the root, the stem, the seeds, or the fruit. Fungi are composed of a mass of branching threads. These threads may gain entrance to the tissues of a plant in several ways. When a spore that has fallen on a leaf begins to germinate, the growing tip may pass through one of the stomates in the leaf and thus reach the active tissues. Spores may reach the interior of a plant through wounds. For example, when a branch of a tree is cut off and the surface is left exposed, the spores can enter. From these spores there may develop threads which enter the living tissues of the tree and send out little suckers which pierce the cell walls and absorb the nourishment from the cells. Besides injuring the plant by robbing it of its food, it may also secrete poisons which have a harmful effect on the plant.

How are plant diseases spread? The fungi that cause plant diseases reproduce by means of microscopic spores. They are produced in enormous numbers and are spread by several agencies of which wind is probably the most important. The spores are so light that they are easily borne by the wind, sometimes to great distances, and so may be carried from leaf to leaf or plant to plant. Insects may also be a means of spreading plant diseases. Recent studies indicate that insects do more harm in this way than was formerly realized. Rain is another means of spreading spores. In the surface streams that form after a heavy rain the spores may be carried a considerable distance.

Man himself is an important agent in spreading these diseases. Seeds, bulbs, and tubers which are already infected may be carried for long distances. Spores may be carried by the different means of transportation — automobiles,

trains, and even airplanes. New plants that are brought into the country from foreign countries may be diseased.

What are some examples of plant diseases? Plants which are attacked by diseases show certain signs by which we may know that they are diseased even though we cannot see the fungi that cause the disease. The symptoms that plants exhibit make it possible to classify plant diseases into certain types.

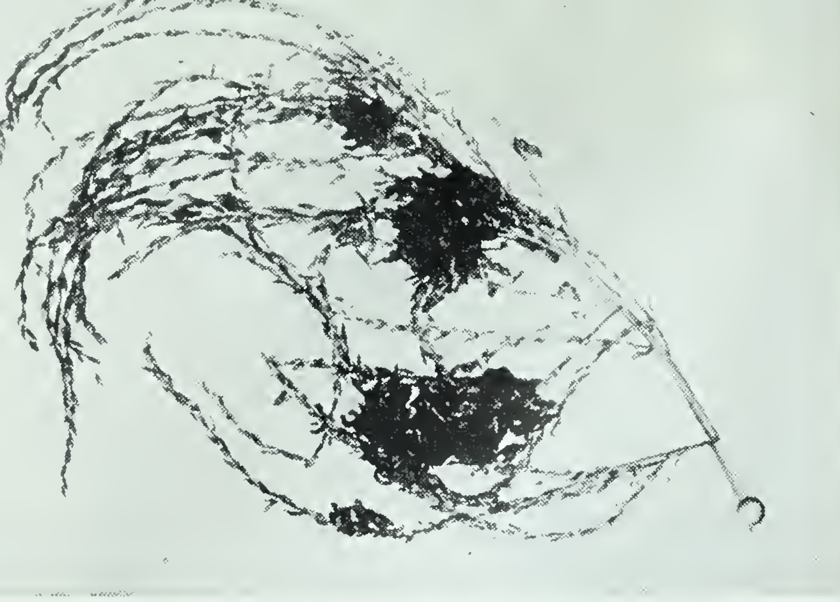
Courtesy U. S. Department of Agriculture

The cedar gall attacks cedar trees, causing the formation of unsightly knots of woody material. The spores may then be carried by the wind to apple trees, causing much damage. Too extensive an attack may ruin the appearance of a tree, or it may even kill the tree.

Examples of plant diseases are blights, wilts, smuts, mildews, rusts, and rot. Blights most commonly attack leaves and cause them to dry up very suddenly. Wilts are diseases which cause the plant suddenly to wilt and droop. The chief symptom of smuts is the production of black dusty spores, usually in the seed head. Rusts are recognized by the rusty-red or orange color of the masses of spores which occur on the leaves, stems, or fruit of many plants. Among the rusts are found some of the most destructive diseases that attack crops.

What is black stem rust? The black stem rust found on grains is the most destructive of all the plant diseases. The chief harm is done to wheat, but it also attacks oats, barley, and rye. The average yearly loss amounts to many millions of dollars.

The fungus that causes this disease must have two hosts to live on in order to complete its full life history. These two hosts are the common barberry and wheat or some other



© General Biological Supply House

Smuts frequently attack the flowers or seed heads of grains. The smut spores are black or dark in color. They destroy the food value of grain crops.

grain. It lives first on one and then on the other. During this complicated history it passes through three stages and forms three kinds of spores: the red, or summer stage; the black, or winter stage; and the yellow, or spring stage. The red and black stages are found on the wheat and the yellow stage on the leaves of common barberry.

In the spring the spores are blown from the barberry to the wheat where it lives on the stem and leaves and grows rapidly, producing red spores, which are blown about and may infect other plants. A new crop of spores may be formed every 10 days. This is called the repeating stage. These summer spores cannot live over the winter in regions north of Texas. In the autumn there appears the black stage, which passes the winter on the stubble and old straw. In the spring, spores are carried to the barberry, where clusters of yellowish spores are formed. These spores are blown to the wheat and thus the cycle goes on.

The best way to control this rust is to destroy the barberry. Bushes may be dug up or they may be killed by applying salt or kerosene to their roots. However, it is necessary to distinguish between the common barberry, which is harmful, and the Japanese barberry, which is entirely harmless and is widely used for ornamentation of home grounds. During the summer the two kinds are easily recognized. The leaves of the common barberry have small spines on the edge, while the leaves of the Japanese barberry have a smooth edge.

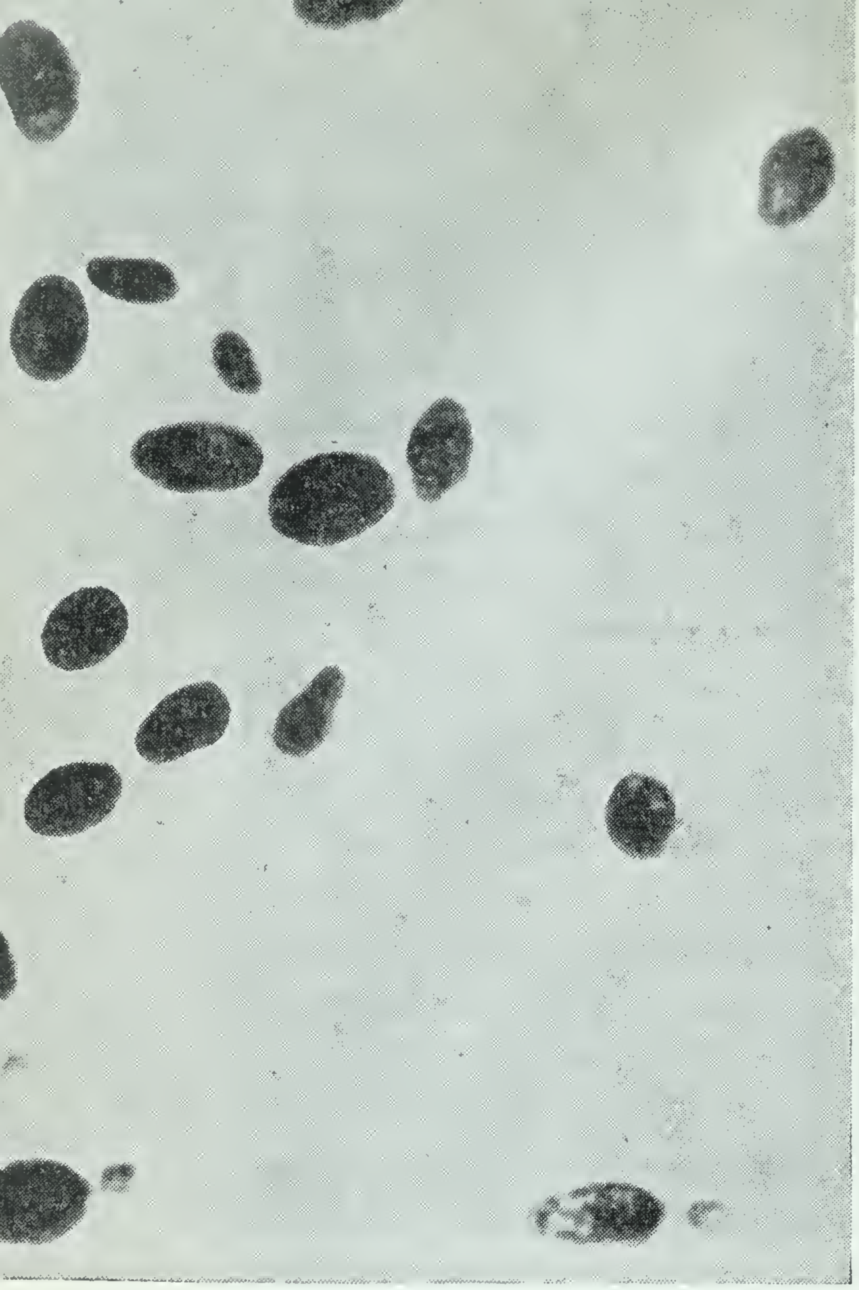
How are plant diseases controlled naturally? Certain factors naturally help to restrict the spread of diseases. A certain disease is generally confined to one plant or to a group of closely related plants. Since the stem rust which attacks wheat does not attack apples or potatoes, the spores that fall on plants other than wheat do no harm. Many fungi

can live only on some certain part of the plant. The brown rot of peaches is found only on the fruit and seldom does any harm to the leaves or stem. Sometimes the period during which the fungus can harm a plant is limited to a certain stage in the plant's development. The stinking smut of wheat must attack the young shoots within a few days after germination in order to do any harm. Since some fungi require two hosts, if either host is destroyed the fungus cannot continue its development.

What cultural methods help control plant diseases? Certain farm practices help to control plant diseases. One of these is rotation of crops. A plant disease is usually limited to one crop, and if the kind of crop that is grown in a field is changed, the spores of the disease that attacked the last crop will not usually attack a new plant. The destruction of weeds also helps to solve the problem, for plant diseases may first live on weeds and then transfer themselves to neighboring crops. For similar reasons it is well to burn the old leaves and dead stalks in the autumn or to plow them under. Sometimes the time of planting seeds may have some influence on the harm that the diseases do. If the seeds of wheat and oats are sown very early in the spring, the plant may quickly develop past the stage when it is affected by the disease.

How are chemicals used to control plant diseases? Various chemicals may be used in several ways in controlling plant diseases. When branches of trees are cut off, spores of the fungus rot may be prevented from entering the wound by applying a thick coat of paint. When seeds are covered with spores, the spores may be killed by treating the seeds with such chemicals as copper sulphate or formaldehyde. Wheat seeds are treated in this way for smut and seed potatoes for potato scab.

Chemicals may be applied to the plants in the form of a spray or dust. When the threads of the fungus grow on the surface of the leaves or fruit, as mildew does, they may be killed by the application of the proper chemical. Usually, however, the threads are inside the tissues of the plant where they cannot be reached by chemicals. Chemicals are used to kill the spores of these fungi.



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The cells of yeast are tiny. A few cells in this group are forming buds, which soon become new plants.

During the fall or winter, while fruit trees are dormant, chemicals are applied in sufficient strength to kill the spores that may be wintering there. Other sprays are applied during the growing season, covering the plant with a thin coating of chemical which will kill the spores that may later be brought to the plant. Bordeaux mixture and formaldehyde are two of the most common chemicals that are used for treating plant diseases.

Filmstrips: The nature of plant diseases. U.S.D.A. Barberry eradication protects small grain crops. U.S. D.A.

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* fungi, spores, suckers, black stem rust, hosts, resistant varieties, cultural methods, chemicals, cells, barberry, cedar galls, paint, crop rotation.

9. How do fungi affect our food supply?

The fungous plants affect our food supply in ways other than by causing plant diseases. Some are definitely useful, while others are harmful. The useful fungi are those which improve flavor or make possible processing of food; while the harmful ones are those which cause spoiling.

What work is done by yeasts? Yeasts are microscopic fungous plants which live on carbohydrates. A compressed yeast cake contains millions of them. Yeast may exist in a growing state, a resting state, or in a spore stage.

The chemical reactions brought about by yeast make it of value for raising bread and for making alcohol. The action

is the result of the work of enzymes—chemicals produced by the yeast—on the sugars. The resulting chemical action produces carbon dioxide, water, and alcohol. Alcohol is a chemical compound of carbon, hydrogen, and oxygen. There are many kinds of alcohols, but the commonest are grain alcohol, or ethyl, and wood alcohol, or methyl. The chemical formula of common alcohol is C_2H_6O. All alcohols are somewhat poisonous, and some are deadly even in small amounts.

The commonest use of yeast is for raising bread. At a temperature of about 80 degrees Fahrenheit yeast acting upon the sugar in bread dough produces bubbles of carbon dioxide which are held by the sticky gluten of the dough. When the dough is baked, the holes are left, making the bread lighter. The alcohol is evaporated in the process of baking. The rising of bread makes it easier to chew and to digest. It also makes it more pleasant to eat, and the yeast adds to the flavor of the bread.

Dried yeast cakes are slower in their action than compressed yeast, because dried yeast is in a resting stage and requires some time to start its action.

The production of alcohol is of great industrial importance. It is the chief ingredient of shellacs. It is used in medicine as a solvent in all tinctures. It is used in many other ways to dissolve materials. Alcohol is a fuel of considerable importance, and if the supply of gasoline runs short, alcohol can be substituted for gasoline. Alcohol is now more expensive per gallon than is gasoline and yields only about half as many heat units per gallon. Farm crops in the future may be a major source of power when converted into alcohol.

Wood alcohol is used in somewhat the same way as grain alcohol—as a solvent. It is poisonous and produces blindness. Wood alcohol should not be used in automobile radiators or in any other place where its fumes might reach the eyes.

What gives butter and cheese flavor? Bacteria which give cream and butter a desirable flavor are grown in pure cultures and are sold for producing desired flavors in the finished products. The cream is first pasteurized to destroy undesirable bacteria, and the starter is then added and the bacteria permitted to grow.

Courtesy Westinghouse Electric and Mfg. Co.

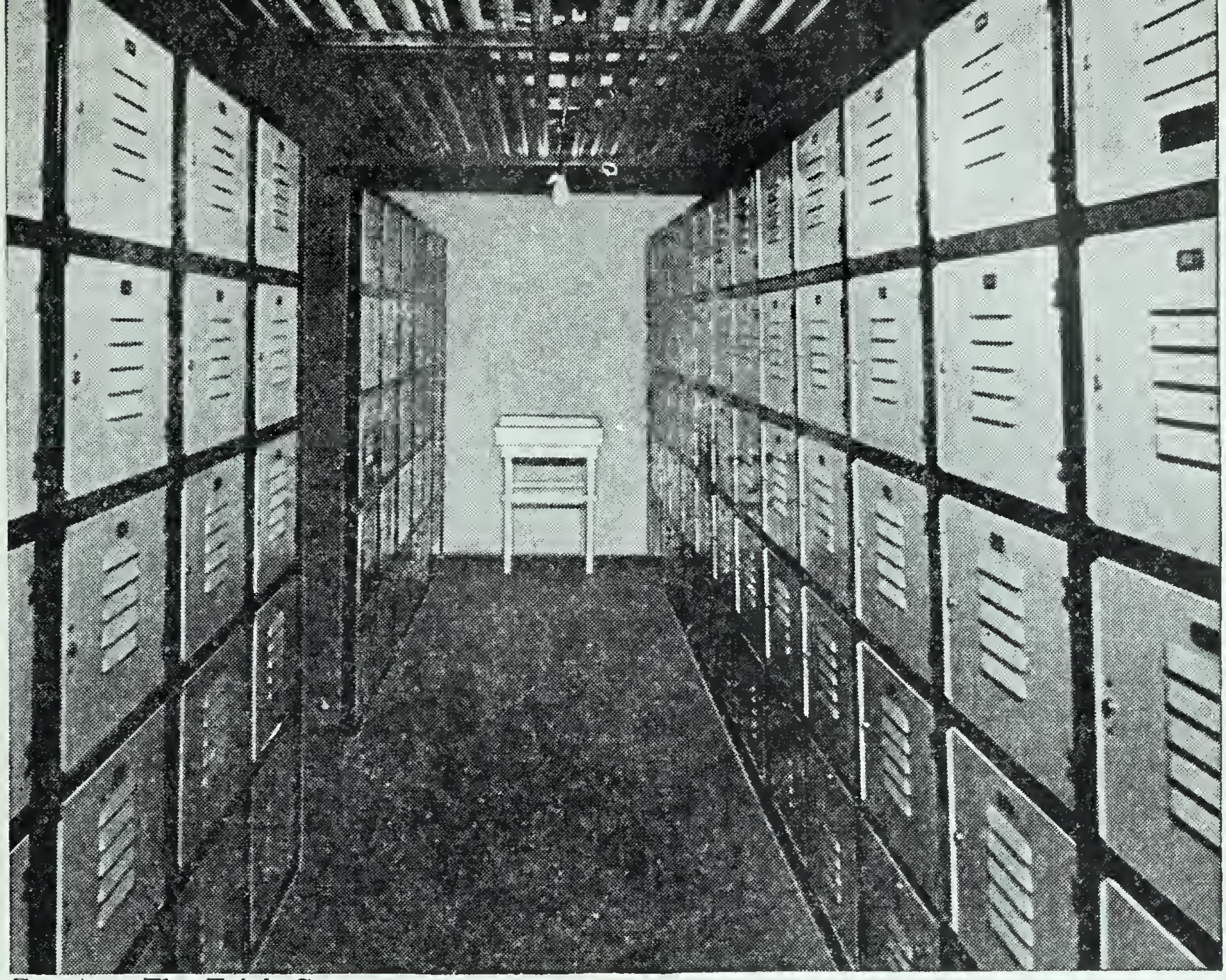
Foods are protected from spoiling in refrigerated showcases. The sterilamps in the case kill bacteria exposed to their ultraviolet rays. These lamps give off little heat.

Cheese obtains its flavor from the action of molds as well as from that of bacteria. Some cheeses show this mold clearly, while others do not. The cheese molds are harmless, and many people enjoy the sharp flavor they give to cheese.

A number of kinds of bacteria sour milk naturally. When milk sours, the sugar it contains is changed to lactic acid. If a sour milk of special flavor is desired, a culture of the desired bacteria is introduced into pasteurized milk. "Cultured" buttermilk is more expensive than ordinary buttermilk.

How do fungous plants destroy our foods? Yeasts cause fruits and sugars to ferment and eventually destroy them if not controlled. Bacteria cause all types of food to decay but act in particular upon such moist foods as meats, vegetables, and fruits. Molds attack stored grains, fruits, jellies, bread, and many other foods.

How do we protect our food from spoiling? Production of foods on farms is of little value if the food is allowed to spoil. A number of methods are used to protect food.



Courtesy The Frick Company

Food-storage lockers are not spectacular in appearance, but their use may revolutionize the eating habits of people in many areas. Frozen fresh fruits and vegetables provide needed foods.

Hay and grains are dried and stored in a dry place. Under ordinary conditions bacteria and molds cannot attack dried foods. High summer humidity may at times permit spoiling to start, however. Foods dried to prevent their spoiling include grapes, apples, apricots, peaches, prunes, and sometimes various kinds of meats.

Freezing and low temperatures retard the growth of bacteria. The packing industry chills all meats as soon as practical after the animals are killed and keeps the meat in cold storage until it is sold for use.

It is often desired to ripen meat by permitting enzymes to act upon the tough fibers to make the meat more tender. Ripening also improves the flavor of meat. Because enzymes work faster at higher temperatures, meat is hung in a room warmer than the storage room, and the bacteria are held in check by ultraviolet rays from a sterilamp. The meat is then cooled again when the ripening is complete.

There are several methods of storing food for home use. The refrigerator is very effective for protecting small

Courtesy Swift and Company

Many meats not only are preserved to some extent by the action of smoke, but are greatly improved in flavor. Smoking removes part of the moisture from meat and deposits certain tars on it.

amounts of food for a few days. Its temperature is normally kept between 40 and 45 degrees Fahrenheit. But the home refrigerator is not large enough to hold half a beef, or the winter's supply of strawberries. For this type of storage, lockers of considerable size are available in many places for rentals of a dollar a month and serve to preserve foods for a long time.

Food is quick-frozen before it is stored. By freezing the food quickly, ice crystals do not penetrate the cell walls, and the food does not spoil so rapidly when thawed out. Quick-frozen packaged foods are now commonly available in stores.

The commoner method of canning food is perhaps the most important way of preventing spoiling. The can is sealed after steam has driven out the supply of air and after bacteria have been killed by heat. No growth of bacteria is possible in the food until the can is opened.

Commercial canneries cook foods, meats, and vegetables under pressure. The commercially canned meats are generally safer than are home-canned meats.

A number of minor methods of preserving foods are still in use. Among these are pickling, preserving, smoking, and salting. Each of these processes produces a chemical environment in which bacteria do not readily grow. But these methods, like freezing, do not kill bacteria in the foods.

Milk is commonly cooled as soon as produced to a temperature of about 50 degrees. Milk which has been properly pasteurized may be shipped in refrigerator cars and still be of fair quality as much as a week after it is produced. It must be remembered that there are bacteria which act at temperatures only slightly above freezing, and they eventually spoil the flavor of the milk, and probably decrease its value, even though the milk is not sour.

Filmstrip: Canning fruits and tomatoes. U.S.D.A.

Exercise. *Complete the following sentences:* When yeasts act on sugars —1— and —2— are produced. The material in bread which holds bubbles is —3—. The chemical formula of alcohol is —4—. The action of yeasts on sugar is due to —5— it produces. The flavor of cheese is caused by —6— and —7—. The temperature of the refrigerator should be about —8— degrees. Canned foods are sealed without any living —9— or any —10— in the can.

10. How do insects affect our welfare?

Insects are by far our worst enemies among animals. The larger animals can be so reduced in numbers that they cease to be seriously harmful. But insects reproduce so rapidly and they are so difficult to find that any permanent reduction in their numbers is out of the question. Each year they reappear in enormous numbers, and each year we must wage our fight over again.

As civilization has advanced in this country, insects have become a more serious threat because of man's activities. When the forests were cleared and more acres were planted to wheat and other crops, a larger food supply was provided for those insects that fed on such crops. And when new crops were introduced, new insects appeared with them. Formerly the potato beetle was found only in Colorado, feeding on wild plants related to the potato. When potatoes were raised there, these beetles began to feed on the potato plants and soon spread to all parts of the country where potatoes were raised.

Also, we have unintentionally brought into this country serious insect pests from abroad. Some of the worst pests we now have were thus introduced from Asia and Europe,

Courtesy U. S. Bureau of Entomology and Plant Quarantine

The potato plants in the foreground were not sprayed and, as a result, were nearly destroyed by Colorado potato beetles. The plants in the background were sprayed.

among these are the cabbage worm and the Japanese beetle.

There are hundreds of harmful insects, but for the sake of simplicity they may be divided into four groups, according to the nature of the harm they do. They injure growing crops. Some insects destroy a great variety of stored products. Others attack domesticated animals. And of course, insects injure man directly by carrying human diseases.

Yet not all insects are harmful because insects pollinate flowers of fruits and vegetables. Some insects are enemies of harmful insects, and of course insects produce honey, silk, and lac, used in making shellac.

How do insects injure growing crops? We and the insects both want the same crops for food. If we did nothing to control potato beetles, undoubtedly they would destroy nearly all the potato crops. Grasshoppers at times destroy

all plants over large areas. Other insects are always present as a menace and at times may become so numerous as to become a serious pest.

As you have already learned, there are two types of insects: those with chewing mouths and those with sucking mouths. Both types are common and destructive. Common examples of chewing insects are grasshoppers and army worms. Army worms, which are a kind of caterpillar, at times appear in countless numbers, and in a short time may destroy a whole field of grain and then pass on to do equal damage to neighboring fields.

Equally destructive are the sucking insects. The presence of chewing insects is indicated by holes eaten in the leaves or by the disappearance of the leaves. The presence of sucking insects is shown by the curling of the leaves or the wilting of the whole plant. Among the most common of the sucking insects are the plant lice, or aphids, of which there are many kinds that may attack a great variety of plants. One of the most destructive is the pea aphid. A machine devised for the purpose collected 11 pounds of these aphids from 2½ acres of peas. Since it takes about a half of a million aphids to weigh a pound, there were about 2,000,000 aphids to each acre of peas.

Some insects feed within the tissues of plants, where they may not be seen. Some of them are called "borers." One of the most common borers is the corn-ear worm, which feeds on the kernels of corn just under the husk at the tip of the ear. Internal feeders, such as the melon worm and the bean weevil, found in fruit and seeds are often called worms or weevils. Some insects spend only one life stage inside the fruit or seed. Other insects spend all their life stages there.

Still other insects live in the ground and feed upon the roots or other underground parts of plants. The white grub (the larva of the June beetle) does damage to potato tubers and to the roots of strawberries. They are apt to be present in newly turned sod.

Insects may injure growing crops indirectly by acting as carriers of plant diseases. The holes left by the feeding insects give an opportunity for the spores in the air to enter

Courtesy U. S. Bureau of Entomology and Plant Quarantine

The apple worm is not a worm. It is the larva of the codling moth. Spraying apple blossoms just as the fruit begins to form kills a large proportion of codling-moth larvae.

the plant. In some cases it is known that the insects introduce the spores directly into the plant on their mouth parts. The Dutch elm disease is carried by a beetle which lives in tunnels beneath the bark.

How do insects injure stored products? Even after the crops have been raised and the products stored for use, they are not safe from the attacks of insects. Man must continue his fight against them. Various kinds of foods, especially those derived from the seeds of cereal crops, are injured in storage by insects. The insects that attack stored food are found chiefly among two groups: beetles and moths. The beetles are injurious in both the larva and adult stages, the moths only in the caterpillar stage. You may have seen larvae of beetles in "wormy" flour or corn meal.

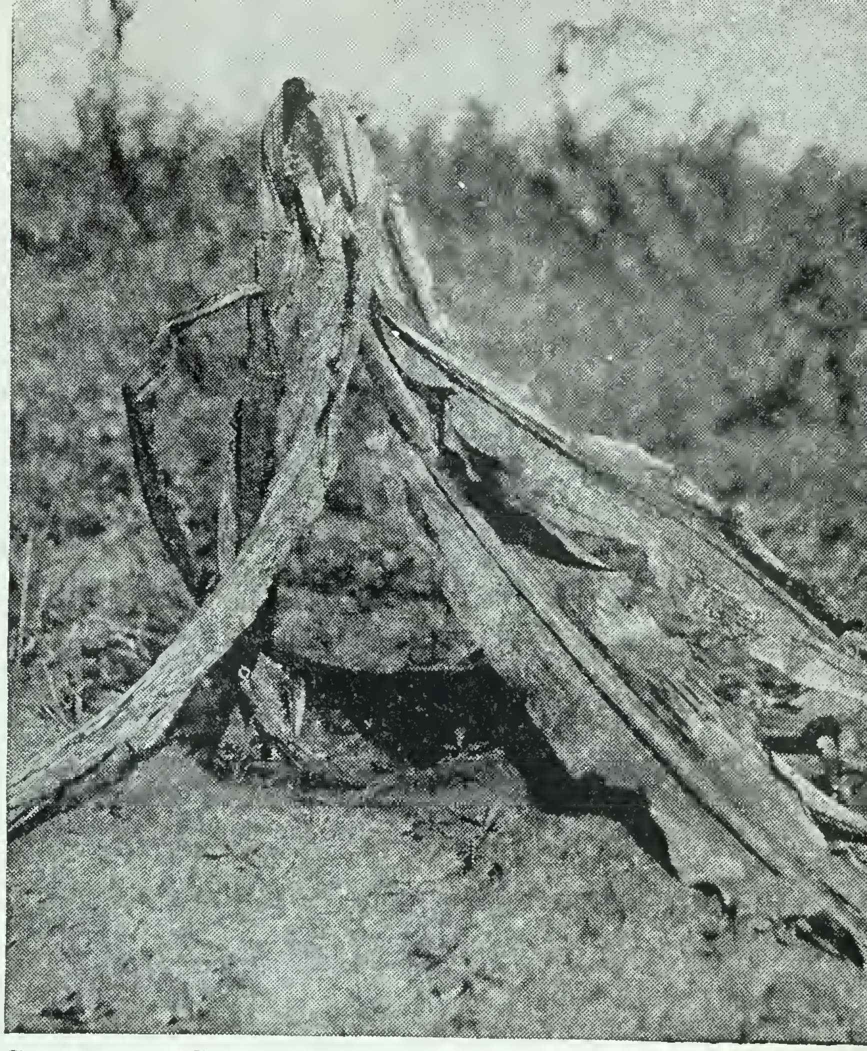
Some insects may even attack wood. Among these is the termite or white ant. It is not really an ant, however. This insect may destroy books or furniture or may even undermine foundations of buildings. It works away from the light inside the part attacked and may do great damage before its presence is known.

A common pest in the house is the clothes moth which, in the caterpillar stage, feeds on fur and woolen goods. It

uses some of the fibers constructing its cocoon.

How do insects injure domesticated animals? Insects attack domesticated animals in a variety of ways. Sometimes they may merely annoy the animals in such a way as to cause a stampeding of horses and cattle.

More serious are those insects that live as parasites on animals. Some of these parasites are external, living on the outside of the animals and sucking blood as do ticks and mites. Some eat dry skin and parts of the feathers, as does the common poultry louse. Other insects are internal pests, living inside the bodies of animals and causing great discomfort and injury. For example, the ox warbler lives just under the cow's skin. It damages the hide, thus rendering it less valuable for making leather. Horse bots live in the alimentary canal of the horse, causing a run-down condition.



Courtesy U. S. Bureau of Entomology and Plant Quarantine

This corn plant was killed by chinch bugs.

What is the total annual loss caused by insects? Careful estimates have been made by experts of the total annual loss caused by insects in the United States. To make this estimate they first find the total amount of each crop raised annually in the United States. Then from a careful study of the situation they estimate the per cent of the crop that is destroyed each year by insects. On the average it is estimated that insects destroy every year about 10 per cent of all crops. The actual amount varies with the crops, in some cases running as high as 20 per cent.

The following table, giving estimates of the annual loss caused by insects in the United States, was taken from Metcalf and Flint, *Fundamentals of Insect Life*.

Harm Done Annually by Insects in the United States

Damage to staple crops (corn, cotton, etc.)	$ 726,000,000
Damage to products in storage	300,000,000
Loss to livestock production	178,000,000
Damage to forest trees and production	130,000,000
Damage to vegetable crops	120,000,000
Damage to fruit and nut crops	88,000,000
Economic loss by insects that carry human disease	50,000,000
Damage to nursery products	12,000,000
Grand Total	$1,604,000,000

Of what value are insects in pollinating flowers? Pollination makes possible growth of seeds. It also causes fruit to develop. These two factors make insects indispensable where many crops are grown. The following list includes a few of the plants dependent upon insects for pollination.

Fruits		*Vegetables*	*Other Plants*
Apples	Oranges	Beans	Clover
Blackberries	Peaches	Cucumbers	Alfalfa
Cherries	Pears	Eggplant	Nasturtiums
Cranberries	Plums	Melons	Marigolds
Figs	Raspberries	Peas	Violets
Grapefruit	Strawberries	Squash	Hepatica
Lemons	Figs	Tomatoes	

It is believed that the value of honeybees for pollinating flowers is greater than their value for making honey.

Filmstrips: Cotton boll weevil control. U.S.D.A.
The Japanese beetle. U.S.D.A.

Exercise. *Complete the following sentences:* The cabbage worm is the —1— of a butterfly. Our worst enemies among animals are —2—. Aphids are insects with —3— mouth parts. Grasshoppers have —4— mouth parts. The white grub is the larva of the —5—. Beetles may be injurious in both the —6— and the —7— stages. Moths are injurious only in the —8— stage. Insects which feed within the tissues of plants are called —9— feeders. Some insects carry plant —10—. The poultry louse is an example of an external —11—. The —12— is an insect that eats wood.

Courtesy U. S. Bureau of Entomology and Plant Quarantine

This duster is applying a poison used to control boll weevils in a cotton field. The poison is blown on the field by power from an engine.

Science activity. Make a collection of definitely harmful insects. Prepare with it an explanation of the harm they do.

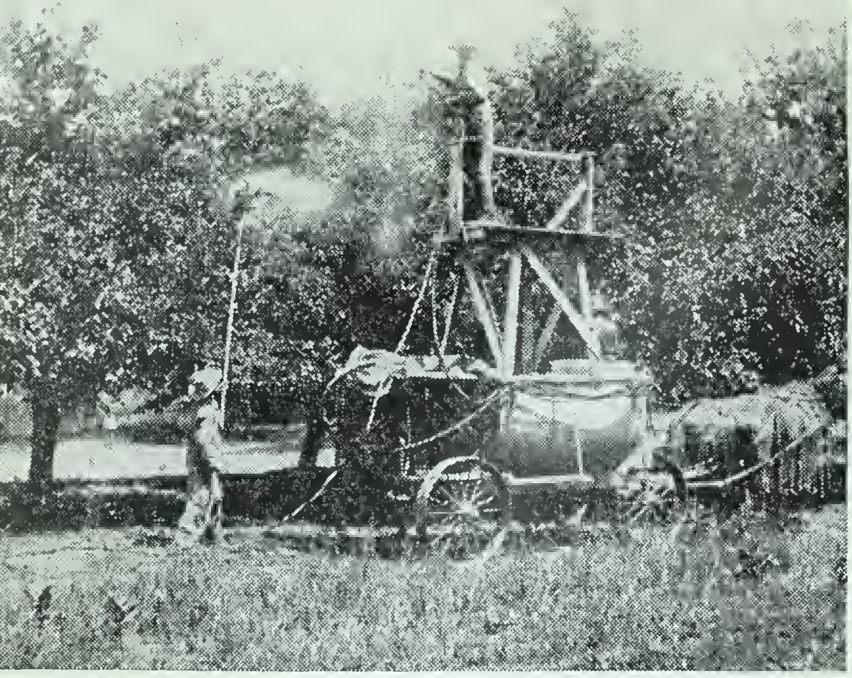
11. How does man control his animal enemies?

Although insects are the worst destroyers of farm produce, we must control all animals that threaten our food supply. Rodents are, next to insects, the worst animal pests we must control.

Many different methods of control have been tried with various insects. All these methods may be grouped under four classes: chemical methods, mechanical methods, agricultural methods, and biological methods.

What are the chemical methods of control? Most chemicals used to control insects are poisons. The kind of poison used to kill insects depends on the kind of mouth parts that the insect has. For chewing insects the animal's food is poisoned. Since this poison is taken into the digestive system of the insect, it is called a stomach poison. The poison may be mixed with some substance that the insect will eat, and the bait scattered over the fields where the insects are found, or the poison may be applied to the plants on which the insects ordinarily feed.

The food for sucking insects cannot be poisoned, since



Courtesy U. S. Bureau of Entomology and Plant Quarantine

This sprayer, which is used to control codling moths and other insects, is mounted on a wagon and operated by a gasoline engine. The two men are able to reach every part of the tree.

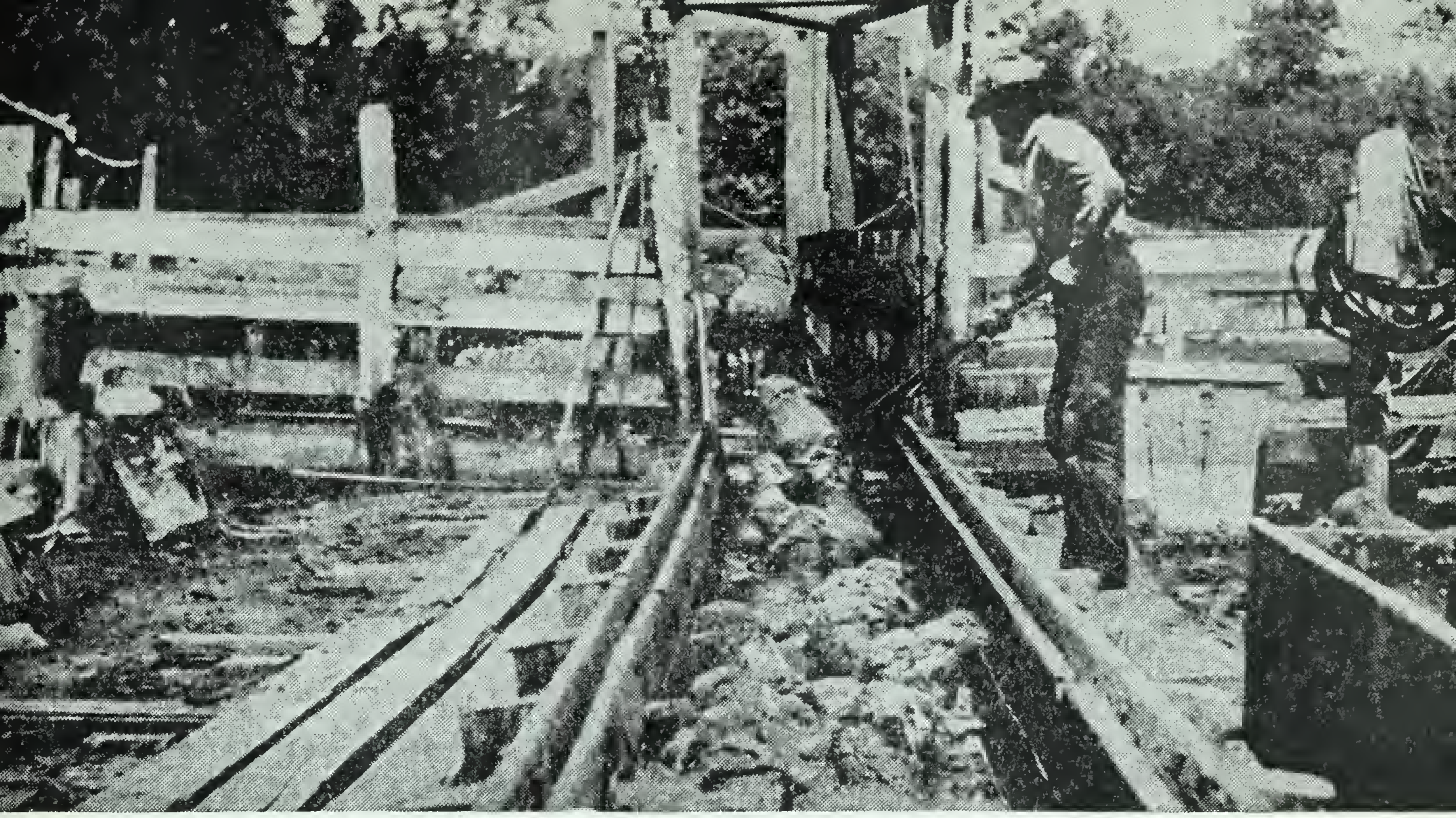
their food consists of sap of plants. To kill these insects, the poisons must be applied directly to the insects. These are called contact poisons. These poisons kill either by clogging the spiracles, or breathing pores, or more commonly, by acting on the tissues of the insect after the poison has passed through the spiracles.

Paris green and lead arsenate are examples of stomach poisons. Nicotine, kerosene, and soaps when dissolved in water at sufficient strength are contact poisons. Both stomach and contact poisons may be applied as a spray or as dust. The kind of sprayer to be used depends on the size of the area to be sprayed. For spraying house plants or a small garden, a small hand atomizer costing a dollar or less may be used. For a medium-sized garden there are several types of hand sprayers available. For large areas power sprayers are necessary. Airplanes have been used for dusting orchards, forests, and large fields of cotton.

The use of poisons involves much expense and labor and, in some cases, risks to the health of human beings. Yet for controlling some insects, no other method is effective.

The potato beetle is kept well under control by use of a stomach poison. The codling moth, a serious apple pest, is controlled by spraying the tree just after the petals fall. If the trees are not sprayed, between 55 and 85 per cent of the apples are wormy. But if the trees are sprayed properly, only 5 per cent or less of the apples are wormy.

Grasshoppers are controlled by using a mixture of bran, poison, and water. This poison is first put out in the spring when the young hatch from the eggs, and as often after that as necessary. The federal government has spent millions of dollars to control the grasshopper.



To kill ticks and other parasites upon sheep and cattle, they are dipped—that is, compelled to swim through a creosote solution. The man with the pole pushes the sheep under.

Spraying is the most convenient method of killing aphids. It is also used in the house for killing flies and mosquitoes.

Some insects can be kept away by the unpleasant gases given off by some chemicals. Oil of citronella keeps away mosquitoes to some extent. Moth balls seem to discourage the adult clothes moth from laying eggs on clothes.

What are some mechanical methods of control? Mechanical methods of control can best be explained by giving specific examples. One such method is to screen windows and doors to keep out flies and mosquitoes. When young tomato plants are first set out, they may be protected from cutworms by wrapping a piece of heavy paper around the stems. The cucumber beetle is a common insect, destructive not only to cucumbers but to such other vine crops as melons, squash, and pumpkins. Most of the harm is done to the young plants. These plants may be protected by placing over each hill a square wooden frame covered with cheesecloth. The egg masses of the tussock moth may be collected during the winter and burned. Sticky bands placed around tree trunks will prevent insects from crawling up the tree.

What are some agricultural methods of control? Agricultural methods include performance of farm operations in

Courtesy U. S. Bureau of Entomology and Plant Quarantine

Bottom left, larvae of the Australian lady beetle feed upon an egg mass of the cottony cushion scale. At the top, the pupa (*left*) and the adult (*right*) are shown. At the right, both larvae and adults feed upon the scale. Lady beetles are predators.

such a way as to destroy insects or prevent them from injuring crops. As you know, both fall plowing and rotation of crops are of value in controlling insects. The time of planting may also be a factor in insect control. For example, wheat planted late is not as seriously affected by the Hessian fly as is wheat planted early.

How are domesticated animals protected from insects? Ticks and lice are among the more common enemies of domesticated animals. Lice on chickens can be killed by dusting sodium fluoride on the feathers of the chickens. Ticks are removed from cattle and sheep by a process called dipping. A large trough is filled with creosote solution and the animals are made to swim through it. The heads of the animals are pushed under the solution by means of a pole. The hair of horses and cows is sprayed with a creosote and oil spray to keep off flies and botflies.

What are some biological methods of control? The most satisfactory method of controlling insects is to permit other living things to keep them in check. Birds, of course, eat many insects. But the greatest factor in keeping insects in check is other insects. Insects may live as parasites on other insects. The eggs of the parasite are laid on the host insect, and as the young hatch they eat the tissue of the host. At first the host is not completely destroyed, but eventually the parasite kills it as the young parasite completes its growth. Some of these parasite insects are almost microscopic. Some are so tiny that they pass their entire life history inside an insect's egg.

Predators are animals which eat other animals. Dragon-

flies, lady beetles, and ground beetles are insect predators which eat other insects. The young ladybird beetles, as well as the adults, destroy aphids. The following table shows the chief differences between predators and parasites.

Parasites	*Predators*
Eggs laid on host	Eggs laid in various places
Host is usually larger	Prey is usually smaller
Feed on one kind of insect	Prey on many kinds of insects
Destroy only one individual	Destroy many individuals
Kill host slowly	Kill prey quickly

One of the unfortunate effects of spraying is that predators as well as pests are killed.

How do we control rodents? Rodents are mammals with gnawing teeth. The rat is the most harmful rodent in this country. The chief damage done by the rat is in the destruction of food. Rats destroy grain while it is growing in the field. They also eat grains and vegetables after they are stored in bins and cellars. It has been estimated by experts that the crops and other property destroyed annually by rats and mice have a value of $200,000,000. Rats also eat eggs and young chickens. Fleas bearing the germs of bubonic plague may be carried by rats.

One of the best ways of lessening the harm done by rats is to keep them out of buildings by use of concrete foundations. They may be killed by means of traps and poisons. Cats are of little use in catching rats. Rat terriers are much more effective enemies of rats.

Ground squirrels, gophers, and prairie dogs eat standing crops and damage fields by digging burrows.

Mice and rabbits are other harmful rodents. Rabbits, on account of their size, do a great amount of damage. They eat grain in the field and vegetables in the garden. During the winter they gnaw the bark of young fruit trees. House mice are easily controlled by means of traps. Rabbits can be controlled by traps and poisons. Fruit trees can be protected from rabbits by wrapping tar paper around them. All burrowing animals can be killed by running carbon monoxide from an automobile exhaust into the burrow.

Mice can be controlled by putting poisoned grain in a cigar

Courtesy U. S. Bureau of Entomology and Plant Quarantine

This tiny wasp is laying its eggs in the body of an aphid. The egg will hatch out a tiny parasite which will devour the aphid as it grows.

box. By leaving a small hole in the box, mice are permitted to enter while other animals are protected from poison.

Filmstrips: How to get rid of rats. U.S.D.A.
Controlling parasites of chickens. U.S.D.A.

Exercise. *Make a table by ruling your paper into four columns. Head the columns as follows:* CHEMICAL METHODS, MECHANICAL METHODS, AGRICULTURAL METHODS, BIOLOGICAL METHODS. *In the correct column write the following phrases or words:* rotation of crops, encouraging birds, screens, stomach poison, fall plowing, wrapping stems with paper, importing beetles, contact poison, poison bait, sticky bands on tree trunks, late sowing of wheat.

Science activity. Make a successful trap for catching sparrows, rats, mice, or flies. See U.S. Department of Agriculture bulletins.

12. Why should most birds be protected?

The practical value of birds depends on their food habits. When they feed upon things that are harmful, such as injurious insects and weed seeds, birds are useful. When they feed on things that are valuable, such as fruit and grain, birds are harmful. Careful studies of the food habits of birds have shown that the good that birds do in destroying harmful pests is many times greater than the slight harm they do in eating valuable products. No other group of common animals has so few harmful members.

How has the food of birds been determined? For many years the Bureau of Biological Survey has been making a scientific study of the food of birds. Experts examine the contents of the stomachs of hundreds of birds and thus are able to determine on what the bird has been feeding.

For example, in studying the food habits of the robin, more than 1200 specimens were collected from 42 states. The food was found to be about equally divided between animal and vegetable matter. About one-third of its food is

composed of harmful insects, about one-seventh of materials valuable to man (fruit and beneficial insects), and about one-half is composed of wild fruit, which is of little significance to man.

The food habits of practically all our common birds have been studied. By referring to the reports of these studies, the economic standing of any bird can be ascertained.

These studies have shown that birds are of practical value in three ways. They eat harmful insects. They eat weed seeds. They eat rodents.

How do birds help control insects? Insects constitute the chief food of our songbirds, and for many birds, insects make up practically their entire diet. Although some of the insects eaten are beneficial, the great majority are harmful to man.

Picture by Dr. W. J. Breckenridge

The short-eared owl is a mouse-eater. The average stomach examined contained one or two mice.

Birds are so active, and the temperature of their blood is so high (from 102 to 112 degrees Fahrenheit) that they require large numbers of insects to supply sufficient energy for life.

Most birds feed on many different kinds of insects. The cuckoo is known to feed on at least 65 kinds of insects, the robin on 229 kinds, and the nighthawk on 600 kinds.

Many of our common insect pests are eaten by a great variety of birds. The potato beetle is eaten by at least 26 kinds of birds, the white grub by 57 kinds, and the cutworm by 88 kinds.

Almost everywhere that insects are found, birds are pres-

L. W. Brownell photo

While the diet of sparrows generally consists of seeds, the young are fed on caterpillars and other forms of insect life. This is a field sparrow mother and young.

ent to feed upon them. Swallows capture insects in the air, woodpeckers drill holes in the trunks of trees and spear insects hidden there. Native sparrows feed on insects found in the ground. Some shore birds devour mosquito wigglers. Many birds collect insects from the leaves of trees.

Do birds eat weed seeds? Many birds are beneficial because they feed on weed seeds. However, not so many birds feed on seeds as on insects. No bird feeds entirely on weed seeds. The two champion weed-seed eaters are the mourning dove and the horned lark. Weed seeds form nearly two-thirds of the food of these birds. Other birds that feed on weed seeds are the native sparrows. Weed seeds make up about half of their food.

Seven hundred seeds of pigeon grass have been found in the stomach of a tree sparrow, and 10,000 seeds of pigweed in the stomach of a bobwhite. Professor F. E. L. Beal estimates that tree sparrows in the state of Iowa eat 875 tons of weed seeds every year.

What birds eat rodents? Hawks and owls are valuable because they eat mice and other rodents. Probably no group of birds is so much misunderstood as these birds. It is a quite common but mistaken notion that they are harmful. Some hunters believe that they are performing a good service when they shoot a hawk or an owl.

From the standpoint of their relation to man, U. S. Bureau of Biological Survey studies show that hawks and owls may be divided into three groups: beneficial, harmful, and neutral—that is, birds in which the harmful and beneficial qualities about balance.

The bulletin summarizing the results of the studies made of the food habits of the hawks and owls states: "The result proves that a class of birds, commonly looked upon as enemies to the farmer, and indiscriminately destroyed whenever occasion offers, really rank among his best friends, and with few exceptions should be preserved and encouraged to take up their abode in the neighborhood of his home. Only 6 of the 73 species and subspecies of hawks and owls of the United States are injurious. Of these, three are so extremely rare that they need hardly be considered, and another (the fish hawk) is only indirectly injurious, leaving but two (the sharp-shinned and Cooper's hawks) that really need to be taken into account as enemies to agriculture."

A former chief of the Bureau of Biological Survey estimated that each hawk and owl is worth $20 a year to the farmers on account of the rodents and insects it destroys.

Are there any harmful birds? Although birds as a class are beneficial, a few birds in some ways do a little harm. Probably the chief harm done is in the destruction of fruit and grain. However, most of those birds still do more good than harm. But there are a few birds which, taking all things into account, must be considered harmful and not worthy of protection. The English sparrow is one because it drives away martins and bluebirds and eats grain; it does little useful work. The sapsucker injures trees. The sharp-shinned hawk feeds on valuable birds, and Cooper's hawk feeds largely on poultry. Perhaps others are definitely harmful under differing circumstances.

Are there fifty-fifty birds? There are several birds whose good and bad qualities about balance. The crow and the crow blackbird, or grackle, are examples of such birds. They are harmful because they eat grain and other birds' eggs, but do good by eating insect pests and weed seeds.

Is bird study a source of pleasure? Many more people enjoy birds of all kinds than hunt game birds. The pleasure

Food Chart of Ten Birds

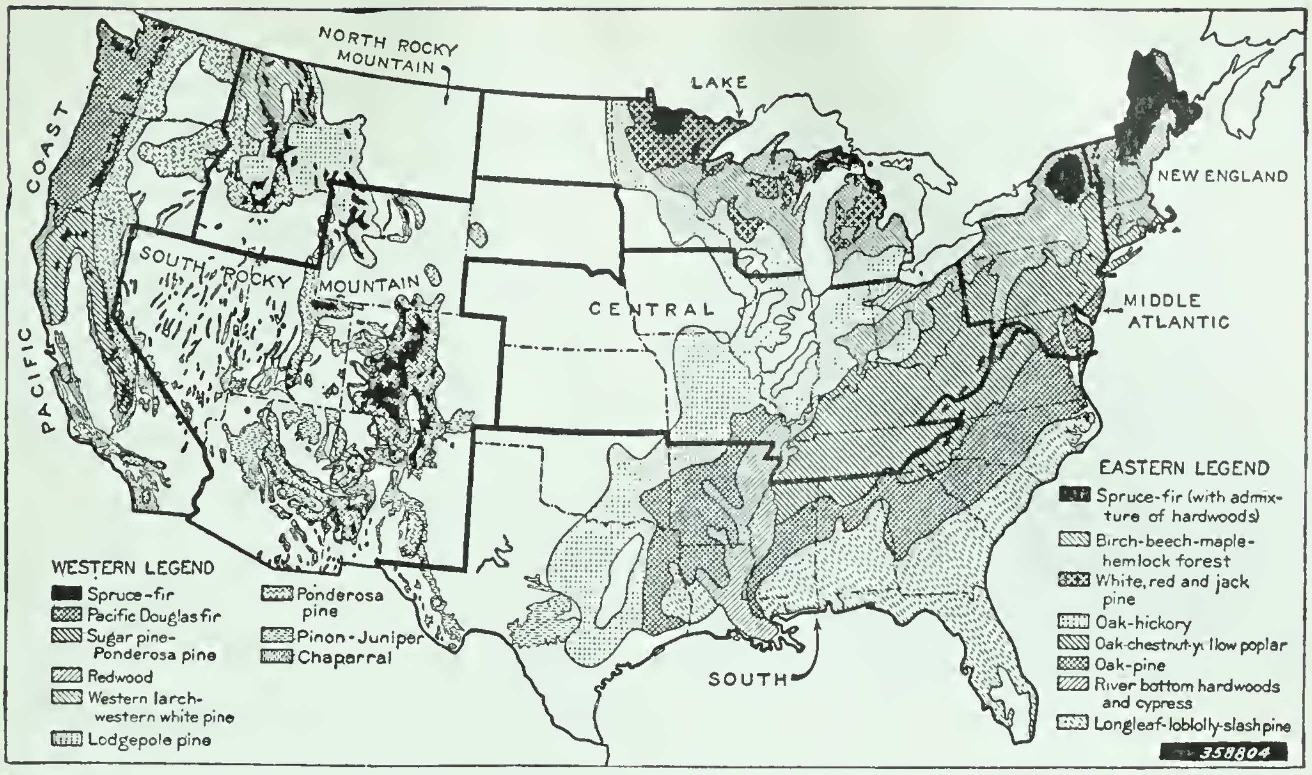
NAME OF BIRD	GOOD DONE		HARM DONE			
	WEED SEEDS (PER CENT)	INSECT PESTS (PER CENT)	GRAIN (PER CENT)	TAME FRUIT (PER CENT)	GOOD INSECTS (PER CENT)	GENERAL STANDING
Downy woodpecker	....	69	....	....	2	Beneficial
English sparrow	24	....	74	....	....	Harmful
Flicker	....	55	1	....	2	Beneficial
Grackle	4	19	22	3	6	Doubtful
House wren	....	69	....	....	6	Beneficial
Kingbird	....	50	....	....	13	Beneficial
Meadow lark	7	56	3	....	12	Beneficial
Mourning dove	64	....	8	....	....	Beneficial
Robin	....	33	....	8	6	Beneficial
Song sparrow	50	18	2	....	2	Beneficial

in studying birds comes from identifying them, watching them for habits peculiar to each kind, recognizing them by their songs, and observing how they build nests and feed their young. People also derive much pleasure from making nesting boxes, feeding the winter birds, and providing fountains where birds may bathe and drink.

Filmstrip: The value of birds in relation to agriculture. U.S.D.A.

Exercise. *Complete the following sentences:* The quail is valuable in destroying weed seeds and —1—. —2— birds are a source of pleasure to millions of hunters. The worst bird all over the United States is the —3—. Most —4— and —5— are useful because they feed on rodents. —6— make up most of the food of songbirds. Our native sparrows feed on both weed seeds and —7—. The most useful enemy of insects is —8—. A harmful woodpecker is the —9—. The most destructive hawk in destroying poultry is —10— hawk.

Science activity. Make a bird chart by keeping a record of the birds you have seen, where and when you saw them, and, if you saw them eating, what they ate. The birds may be identified by use of a bird book. *A Guide to Land Birds,* by Chester A. Reed, is excellent. Good books may be bought in dime stores.



Map by U. S. Forest Service

This map shows to some degree how complex the mixture of forest trees really is. Study it in detail, particularly in your locality.

13. What is being done to conserve our forests?

The forests are of such great value that we cannot well survive as a nation without them. Forest conservation is one of the most important phases of man's control of his living environment.

Forests provide us with wood, lumber, and paper. They protect grass in public grazing lands. The forests protect the watersheds of streams and are of value in protecting against droughts and floods. The national forests furnish recreational opportunities to nearly one-fourth the people of the United States every year. Forests offer protection to wild life, particularly to the large mammals which formerly were in danger of becoming extinct. About a million and a half big game animals dwell in the national forests.

Who owns the forests? About one-third of the land of the United States is covered with forests. Of this land, the states and the federal government own about 30 per cent, and the rest is privately owned. The management of the publicly owned forests is much superior to the management of privately owned forests, as is shown in the following table:

	PUBLICLY OWNED FORESTS	PRIVATELY OWNED FORESTS
Under scientific management	90%	14%
With adequate fire protection	95%	55%
Areas burned annually	$3\frac{1}{2}$ million acres	40 million acres

Is there need for conservation? When the white man came to this country, he found most of the land covered with large forests. He found it necessary to cut down some of these forests to provide room to grow crops to supply himself with food. As time went on and the population increased, the remaining forests attained a high commercial value for the lumber they contained. Naturally the lumber companies took no thought of the future but cut the forests in such a way as to obtain the greatest financial returns.

The national government is trying to improve forest management in three ways: by acquiring more land for national forests, by educating and cooperating with private owners in management of their land, and by passing of laws to permit the public regulation of private forest lands. These steps were necessary to remedy the poor management of privately owned forests.

Why do we have national forests? The forests were cut so recklessly and so many were destroyed by fire that eventually the point was reached when the question of saving the forests for the use of future generations became a serious matter. It was at this point that the federal government began to take steps to conserve the remaining forests. Private owners could not be expected to look to the future and manage these forests with the thought of the public welfare in mind. But the federal government could and did take this viewpoint of conserving our forests for the use of both the present and future generations. Since the first forest reserve was created in 1891, others have been added until at the present time there are about 160 national forests with a total area of about 174,000,000 acres. These national forests are located in 40 states and 2 territories.

There are now about 200 million acres of timber in such poor condition that they are valueless unless taken over by

the public and reforested and otherwise brought into production of trees. The state and federal governments buy land voluntarily offered for sale, if the acreage is large enough to make possible economical management. The area of the national forests is constantly being enlarged.

What is the U. S. Forest Service? The management of the national forests is in the hands of the U.S. Forest Service. Altogether the permanent force of the Forest Service numbers about 5500 persons. Foresters are trained in four-year university courses.

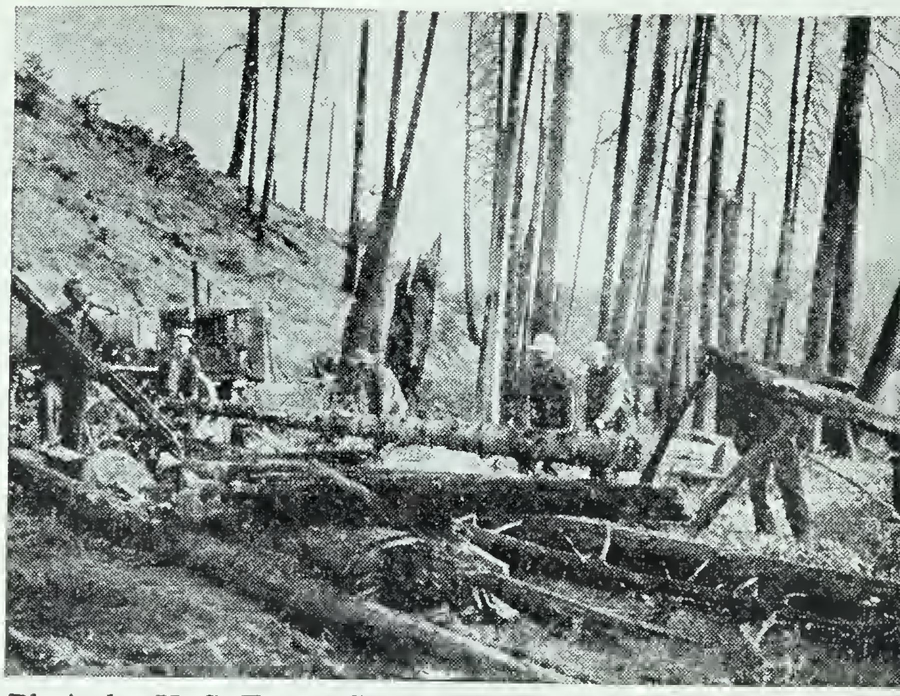


Photo by U. S. Forest Service

In a burned-over area, there are many dead, fallen trunks. These are removed to provide space for the growth of pine seedlings which are to be planted.

What protecting does the forest require? The three chief enemies of the forest are fires, insects, and plant diseases. The worst of these is fire. The six chief causes of forest fires on protected areas are shown in the following list.

Incendiarism (Setting fires on purpose) . . .	26 per cent
Smokers	25 " "
Debris burning	13 " "
Lightning	8 " "
Campers	7 " "
Railroads	4 " "

The total number of forest fires yearly is about 168,000. These burn over an area of some 40 million acres and do damage amounting to 50 million dollars.

Our national forests are well protected against fires. During the danger season the forests are patrolled systematically, and a careful lookout is maintained from towers on high points. Roads and trails make it possible to reach all parts of the forests quickly. Telephone lines connect the ranger stations and lookouts with the office of the supervisor. Supplies of food and tools for fire fighters are kept stored at convenient places. In recent years use has been made of aircraft as an aid

Photo by U. S. Forest Service

Pine seedlings are started in a nursery and set out in the forest by young men, working under the direction of the Forest Service of the United States Department of Agriculture. Our future forests depend upon such work.

in fighting fires. Methods have been devised for dropping equipment and supplies to fire fighters from airplanes. Aircraft are also used for scouting and patrolling large fires. Many of the national forests are equipped with portable short-wave radio sets. These are used as an aid in reporting progress of the fire.

Does scientific management improve forests? Principles of scientific forestry are followed in the care of the national forests. Instead of cutting down all of the trees at one time, as was done formerly, only the large mature trees are cut. By following this policy the forests may continue to yield lumber indefinitely.

Standing timber which is large enough to be cut is sold at a fair price. The trees to be cut are usually marked in advance by a forest ranger. In order that later crops of timber may be cut from the same land, younger trees are carefully protected and enough trees left to seed the ground.

Some sections of the forests have been devastated by repeated fires and by reckless lumbering. When this devastation has reached such a stage that desirable forest growth will not naturally occur, it is necessary to plant young trees on such areas. The Forest Service now has 30 tree nurseries with a capacity for producing annually a quarter of a billion young trees. During the three-year period 1934-36 more than 400 million trees were planted in the national forests, thus reforesting an area of more than 400,000 acres.

What do research laboratories do? Another important line of activity of the U. S. Forest Service is its work in research. For carrying on this work there is a national institution at Madison, Wisconsin, known as the Forest Products

Laboratory. In addition, there are 12 regional experiment stations located in the major forest regions of the country. The purpose of the research is to find out how better use can be made of the products obtained from the forest and how the methods of caring for the forests can be improved. The Service maintains experimental forests, in which much of the research is carried on. Methods which have proved successful can then be applied on a large scale in all of the national forests.

Photo by U. S. Forest Service

One of the means of fighting a forest fire is to dig a strip of land clear of all vegetation in the path of the fire.

Does cooperation with private owners improve forests? An important line of work of the Forest Service is its cooperation with private forest-land owners, looking toward better management of American forests as a whole. The importance of this cooperation is evident when we recall that about 70 per cent of the forests of this country are under control of private owners.

What has the C.C.C. done to improve forests? The Forest Service has been greatly aided in its work of caring for the national forests through help given by the Civilian Conservation Corps. The Forest Service estimated that in four years its program was advanced 15 to 20 years through the aid given by the C.C.C. All forest projects of the C.C.C. camps were planned and supervised by experts from the forest service. The C.C.C. boys were particularly helpful in fighting forest fires and in planting young trees.

Filmstrips: Forest conservation. U.S.D.A.
Saving our white pines from blister rust. U.S.D.A.

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* conservation, national forests, U.S. Forest Service, seed, reforestation, fires, C.C.C., cooperation, smokers.

Photo by T. J. Watkins, U. S. Forest Service

When animals are deprived of their natural range by man, they must be fed if they are to survive. These mountain sheep are being given food in a national park.

Science activity. Collect leaves of 10 trees and make leaf prints. Put them on a card or poster, properly labeled.

14. How can we conserve wild life?

Three types of wild life are in particular need of protection. Some are of great value for the pleasure they provide hunters and fishermen. But some of these animals are of still greater value in maintaining a balance of nature to make our own food supplies more secure. These wild mammals, birds, and fish are in too many cases decreasing in number to the point where they may be unable to survive.

What wild mammals need protection? There are a few mammals which are destructive pests or capable of surviving in spite of man. These animals, which include foxes, wolves, ground squirrels, woodchucks, weasels, red squirrels, and wildcats, may be hunted any time. Another group is sometimes plentiful enough that they may be hunted part of the year on occasional years. This group includes deer, bear, muskrat, rabbits, raccoons, skunks, gray and fox squirrels, beaver, and mink. Another group is so nearly extinct that no hunting should be permitted. These rare animals include badgers, caribou, elk, moose, fishers, martins, and otters.

Some of these are of value for their meat, some for their fur, and a few for both. Muskrats, skunks, raccoons, and squirrels are common and valuable fur bearers. Beavers and minks are not common, but their fur commands high prices.

How may mammals be protected? The most important immediate protection required is regulation of hunting and trapping. The hunting should be regulated by state game department experts who have authority to close the hunting

season as necessary to protect animals in need of protection. It is almost as necessary to permit hunting of animals which are becoming so numerous that they are likely to destroy their own feeding grounds.

Over a longer period of time it is necessary to restore breeding areas and the natural homes of wild animals in order that they may have a place to grow. Game refuges should be established in national and state parks, in waste lands, and in swamplands. Swamps should be left for muskrats and other swamp dwellers, as well as for the purpose of regulating water supply and stream control. Swampland devoted to raising muskrats actually yields more income than do equal areas of the average farm.

Game propagation on farms is not very successful, but game farms may be of some value for certain species.

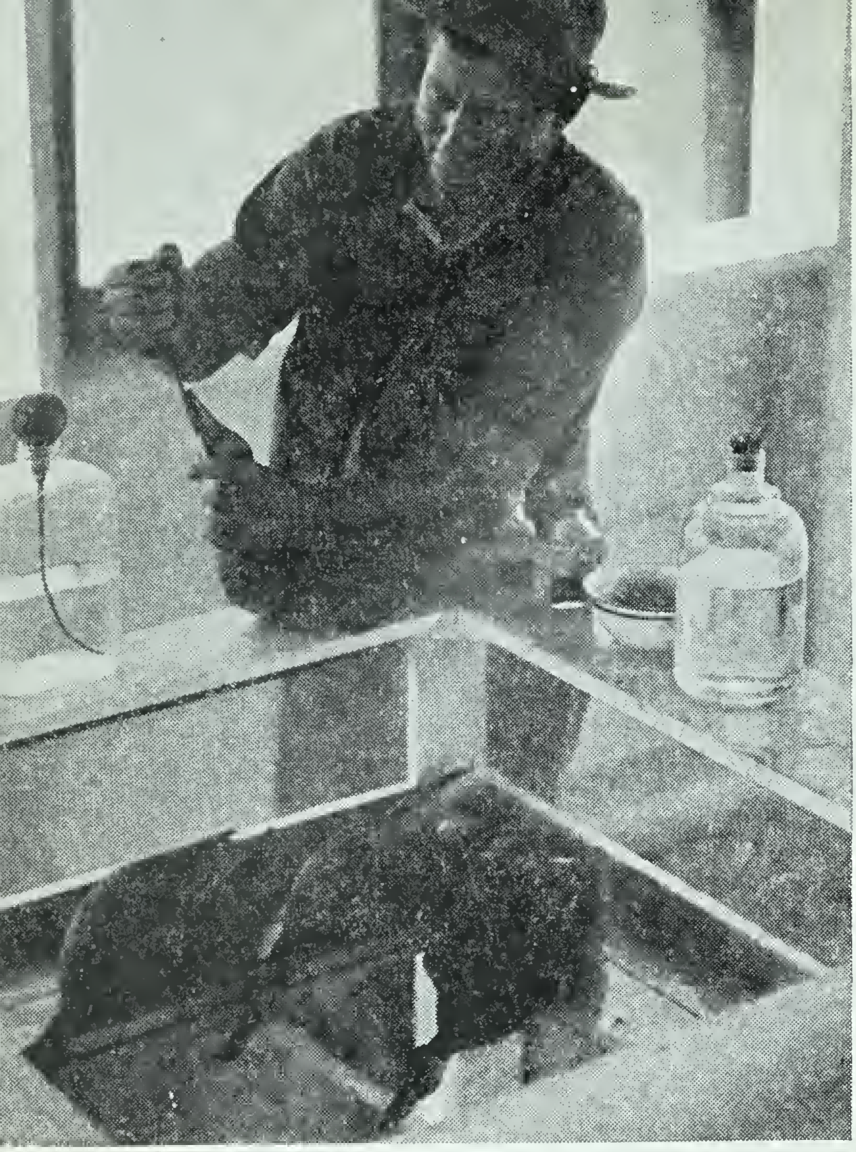
Are there many wild mammals left? Deer are the most plentiful large mammals. More than 50,000 are killed every year, and they seem able to maintain their numbers. There are now about 165,000 antelopes and not quite as many bears in this country. There are about 5000 bighorn sheep in the Southwest. There are about 25,000 elk in the Yellowstone Park area. In all, there are only about six million large game animals in this country, or one for each 22 people.

About five million muskrat skins are sold every year to make Hudson seal fur. More than a million skunk skins are sold yearly. Wild rabbits are so common that they easily become pests.

What valuable birds need protection? There are two kinds of game birds: the upland birds and the waterfowl. The songbirds and the hawks and owls also need protection.

The upland game birds are permanent residents and consist of quails, pheasants, and partridges. These relatives of the common chicken live on insects, weed seeds, and small grains left in fields and are valuable in controlling weed and insect pests. They are also excellent for shooting because they are fast-flying and clever. Their flesh is excellent food.

The waterfowl are chiefly ducks of various kinds, for wild geese and swans are practically extinct in this country. The ducks breed in the northern states and Canada, then fly south in the autumn, rest in the southern states during the



Courtesy U. S. Bureau of Biological Survey

Ducks get sick from a number of causes. This duck is in the hands of a doctor receiving treatment—apparently not on an entirely voluntary basis. This work is carried on by the Bureau of Biological Survey of the United States Department of Agriculture.

winter, and return north in the spring.

How can birds be protected? It is essential that most songbirds be protected from shooting at all times, and all states and the federal government have laws providing this protection.

Upland game birds require protection at all times except for a short time in the autumn, when there may be more birds in many regions than can find food during the winter. Shooting should be limited to the excess, for many of these birds will die of starvation or be eaten by foxes if not taken by man. Each state game department must decide how many birds may be shot.

Waterfowl are protected by the federal migratory bird law and by treaty laws between Canada and the United States. These laws regulate the time of shooting birds. Each state has the authority to regulate the number of birds that may be shot. Many birds, such as the wood duck, do not reproduce in numbers sufficient to make shooting advisable at any time.

Still more important is the protection required for the breeding places of birds. Upland birds need grass and underbrush for cover. Ducks require an abundant and dependable supply of water. Refuges for both kinds of birds are provided in many states, and more are needed. Swamps worthless for other uses provide excellent areas for bird refuges.

Under the direction of the Bureau of Biological Survey, more than 200 refuges have been established for waterfowl

There are many species of quail. These of California, like others, are beneficial birds both in their eating habits and in their ability to provide sport and meat.

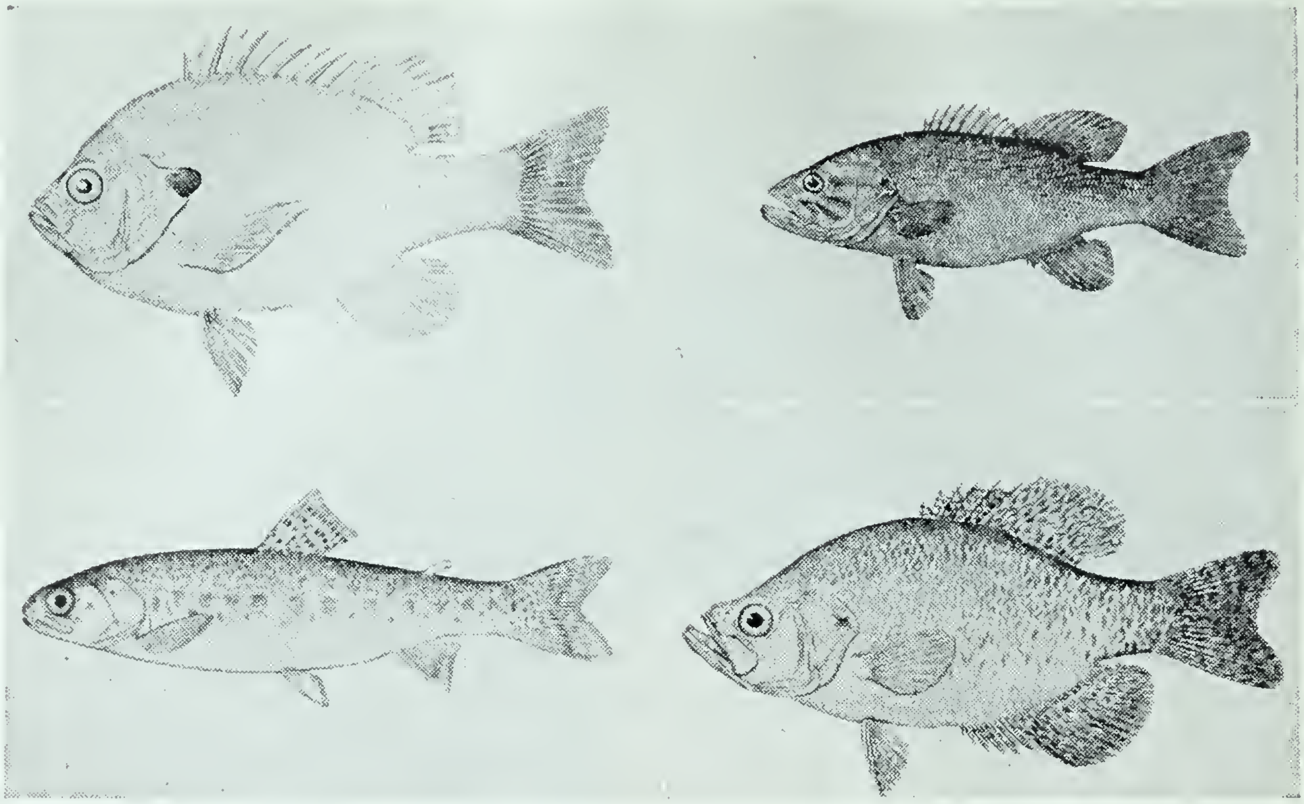
in the northern breeding areas. Some are located along the Mississippi Valley flyway, and others are located in southern resting areas. There are more than 350 state game and bird refuges in national forests.

Upland birds sometimes require winter feeding. This work is done by game wardens and sportsmen's organizations, who build shelters of the correct kind and place grain in them where it will not be lost in the snow.

The chief enemies of songbirds are cats and English sparrows. All stray cats should be killed, and all housecats should be kept indoors at night. Cats claws may be trimmed. Sparrows may be trapped under the right conditions. A government bulletin will tell you how.

What kind of fish require protection? Some fish are a major source of food, but most fresh-water fish are more important as a means of providing sport. Salmon are the chief food fish taken in the United States, and the federal government regulates commercial fishermen who take them. Lakes and streams are usually filled with fish, unless the water has been polluted by silt from farm lands, by minerals from mines, by sewage from cities, or by wastes from factories and canneries. Obviously it is necessary to keep waters clean if fish are to survive.

Fishing is forbidden in the early spring months when the



Courtesy U. S. Fish and Wildlife Service

Many people cannot recognize the common game and pan fish. Perhaps a study of these will help you know these fish when you see them. At the top, is the sunfish (*left*) and the small-mouthed black bass. At the bottom is the brook trout (*left*) and the crappie.

fish lay their eggs. At other times fish may be caught if the number warrants.

How is the supply of fish maintained? Young fish under natural conditions have little chance for survival, for their natural enemies use them for food. Then too, many fish eggs are never fertilized, for the method of fertilization of fish is inefficient. In order to provide a supply of young fish, they are raised in hatcheries. Some of these are operated by the states, some by the Federal Bureau of Fisheries.

Female fish are caught just before they are ready to lay their eggs. The eggs are gently squeezed from the female into a pan of water. A male fish is caught, and the fluid containing sperm cells, called milt, is squeezed from his body over the eggs. In this way practically all eggs are fertilized. The eggs may be returned to lakes and streams if conditions are favorable. But many are left in tanks of water in the hatchery to develop into young fish. The water is kept quiet or in motion as necessary, and food is provided. It has been found that it is best to permit the young fish to reach a fair size before they are planted in streams or lakes.

Photo by U. S. Forest Service

Many millions of people enjoy fishing as their chief outdoor sport. Their fishing license fees help, to a considerable extent, in keeping up the supply of fish in streams and lakes.

It is especially important to release small fish only in places naturally favorable to them. If there is no food available or if the lake is full of hungry, larger fish, they will have little chance to survive.

People who have lake cottages often clean up the lake shore, by removing weeds which protect fish and provide them with food, and still expect to catch fish from the lake. Farmers permit cattle to pollute their ponds and wonder why their carp and sunfish supply decreases. Even a fish needs an environment suited to its needs.

Filmstrip: Fur animals. U.S.D.A.

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* eggs, milt, hatcheries, planting, songbirds, game birds, nesting, game preserve, bird refuge, muskrat, deer, regulation, licenses, migratory, upland.

Science activities. 1) Report on how game department officials decide what kind of fish to put in a certain lake. Learn how a fish census is taken.

2) Make a report on one kind of game or fur-bearing animal.

Include information as to its value, its breeding habits, its natural range, its food, and its chances for survival.

15. How can conservation be practiced on the farm?

Too often we think of conservation on a national or state scale and fail to do what we can where we live. As a matter of fact, conservation on farms, around the home, and in pasture lands is just as important as is conservation on a larger scale.

Can we conserve trees on the farm? There are few farms in the United States that are not better for having trees. The location of the trees, the kind of trees chosen, and the amount of space available determine their value. The greatest single value of trees is their ability to protect the soil against erosion. Sloping hillsides and the tops of hills should always be protected against washing by enough trees to break the force of the rain striking the ground. Almost any kind of tree will serve for this purpose, but the most valuable tree that will grow in the region should be made the chief tree of the wood lot.

The wood lot, if properly managed, will provide a supply of large trees for fuel, fence posts, and some lumber as long as the farm is in use. Since large trees do not grow as rapidly as smaller trees, they should be harvested before decay sets in and before they begin to break in windstorms. In cutting large trees, it is important not to permit them to break and spoil the shape of younger trees as they fall. All branches and waste should be removed to prevent giving pests protection in the dead wood.

The wood lot has some value in maintaining soil moisture, for snow that falls on the ground will last longer in the woods than on bare ground.

In case the land of a farm is already barren because of cutting of trees and erosion, it is sometimes necessary to start reforestation by using quick-growing shrubs and quick-growing trees to cover the ground before more valuable trees can be started. Then gradually more valuable, slow-growing trees can be introduced. Many states provide small trees free for planting on the farm. Some of the finest of American

This farm wood lot is dying. The soil is hard-packed by the hoofs of cattle, and there are no young trees. Note that the nearest tree is dead.

trees—the black walnuts, the oaks, and the maples—are gradually becoming extinct in many regions because they have not been planted to replace basswood, poplars, box elders, and other less valuable trees.

The use of trees for windbreaks is of great value. A row of tall trees will sometimes cause drifting snow to settle on cultivated fields to provide much-needed moisture. Trees provide nesting places for songbirds which search for insects in near-by fields where crops are grown. Few songbirds will nest in the open.

Cattle must not be permitted to stand in the wood lot, for they break down small trees, eat the foliage from the lower branches of trees, and pack the soil with their hoofs until seeds cannot get a start. Any wood lot that is clear of young growth and underbrush is a dying wood lot. If shade is desired for cattle, it is better to plant trees along the pasture fences than to turn cattle into the farm forest.

Where should pasture grasses be grown? There are some slopes that are not steep enough to require trees for protection but still are too steep to retain soil if put under cultivation. These slopes should always be kept planted in tough-rooted grasses or clovers. The tops of hills in particular should be

left in grass, for it is from the hilltop that water starts its journey. A farmer need not be afraid to leave uncultivated areas in his fields, for if he practices plowing across the slope of the hill instead of up and down, he will not be able to plow in straight rows anyway. It is better to have good soil than to have a straight furrow in poor soil. Most farmers use cultivated fields for pasture after crops are harvested, and if there are also areas of grass in the fields, the pasture is of more value.

Pasture must be used wisely or it loses its value for soil protection. It is best to divide pastures into small sections and to move cattle from one section to another, thus giving grass a chance to grow part of the season. Too many farmers permit cattle and sheep to eat the pasture grass as long as they can find any. Weeds are thus left to go to seed, and soon the weeds crowd out the grasses. Erosion starts and, in the packed soil, new grass cannot start growing. The wise farmer will loosen the soil of the pasture occasionally and plant seed of grass which he knows will grow in his region. It is important to chop out weeds before they go to seed.

It is particularly important to plant strips of grasses across the direction of slopes.

Can stream and pond conservation help the farm? Not all farms have streams or ponds, but many could have. There is often a deep gully or low region which catches water part of the season but which is of no value for crops. Such a low place can be used to provide water. It may be necessary to build a dam of earth, rocks, or logs to retain runoff water. The value of the farm pond depends upon the cleanliness of the water, the amount of water, and the regularity of supply. If the pond becomes almost dry in autumn, it cannot be used for fish. But such a pond provides a place for growing domestic ducks, for providing water for cattle, and for attracting birds. Pigs should not be allowed access to the pond, for they destroy all vegetation by rooting.

A larger pond may be used to produce carp and to provide a home for muskrats. Waterfowl will find considerable food in the pond. It is a mistake to clear all trees from the edge of the pond or to permit cattle to kill vegetation in the pond. Farm land in the United States is not so valuable that every


Photo by U. S. Forest Service

Few farms may have a stream as nearly ideal as this for providing pools for fish. But every intelligent farmer can make the most of the water resources available on his farm.

possible inch need be cultivated. In fact, many farmers would do better to cultivate less land but to till it more intensively than they do.

Ponds maintain the water table in near-by soil. They retard erosion and clear streams of mud. Ponds are attractive, and if provided with fish and birds they will not become dangerous breeding places for mosquitoes.

What is fence-row conservation? If a farmer wishes to have song and game birds on the farm, it is necessary to provide nesting places. There are in every region shrubs and small trees that will grow along fence rows to provide for these needs without shading too much of the field. If the fence row becomes too brushy, it is possible to permit sheep to eat away some of the vegetation in the autumn when there are no bird nests to be damaged.

It is well to plant along fence rows shrubs which bear wild berries, for these will keep robins from cultivated fruit and will provide other birds with food when they need it in the autumn. Of course poison oak and ivy, barberry, and other objectionable weeds must be kept out of the fence row.

Should predators be killed? Predators are mink, skunks, foxes, coyotes, hawks, owls, and other flesh-eating animals.

These animals in general are invaluable aids to the farmer in rodent control, and should not be killed If, however, an occasional predator turns to farm poultry or other farm animals for food, that individual should be trapped or shot.

It is not only unwise but unprofitable to set out poison baits to kill all predators in the neighborhood. One of the bad results from poisoning ground squirrels and other rodents is that the predators are killed by eating the poisoned rodents, and the rodents become more numerous than ever.

Is conservation worth while? It has been said that farming is not a job, but a way of life. Since this is true, the hard work of building dams, caring for the land, planting trees, and caring for wild life will not seem to be drudgery, but a form of activity which pays good dividends in pleasure and money. If a person living on a farm wants to follow an eight-hour day and pay no attention to his farm except to drive cultivating machinery across its fields, he is missing the real satisfactions that come from his occupation. For in the long run the future of most of the land in the United States is in the hands of its farmers. If they follow a short-sighted policy of letting the land become worthless, the nation will not long survive as a great nation.

Filmstrips: Farm forestry in the South. U.S.D.A.
Range management in the national forests. U.S.D.A.
The how and why of pastures in the southeastern states. U.S.D.A.

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* predator, pond, water table, erosion, strips, hilltops, grasses, slopes, rodents, birds, cattle, weeds, windbreak, snow.

Science activity. Locate in your community hillsides which should be returned to pasture or to woodland. Arrange to have the owners of these fields supplied with government bulletins on soil conservation. Work out a conservation program for the school grounds.

A Review of the Unit

Man controls his living environment in four ways. He selects and cares for those animals which he wishes to domesticate. He

improves the quality of domesticated plants and animals by selection and by breeding. He kills those plants, insects, and larger animals which are directly or indirectly harmful. He conserves those living things in the natural environment which are helpful by improving their environments and controlling their enemies.

To do this it has been necessary to learn laws of inheritance and to apply them. It has been necessary to experiment with soils, crops, and foods. It has been necessary for man to be always on the alert to study the habits of his animal enemies in order to protect his crops and animals from them. And it has been necessary to develop a sense of responsibility to future generations for preserving desirable forms of life for future use.

An exercise in thinking

Match the principles and related ideas, according to the directions given in the review at the end of Unit I.

List of principles

A. Man selects for domestication or protection those living things which have adaptations suited to his needs.

B. There is variation among the individuals of any given type of plant or animal.

C. Characteristics are transmitted from parent to offspring by heredity through the reproductive cells.

D. An egg cell is fertilized when the protoplasm of a sperm cell combines with it.

E. Man increases the yield of domestic plants and animals by providing them with care.

F. Economically harmful plants and animals are those which destroy the things we wish to use for ourselves.

G. Economically helpful plants and animals are those directly useful to us or those which check our enemies.

H. Man controls his living enemies by destroying them or by making their environment unsuited to their needs.

List of related ideas

1. Life comes only from life.
2. Weeds compete with useful plants for food and water, and reduce yield.
3. Ovules are produced in the part of the flower called the ovary.
4. The codling moth or apple worm is controlled by spraying.

5. The enemy of birds easiest to control is the housecat.
6. Chickens will lay in winter if they are provided warmth and light enough to find food.
7. The reproductive fluid of male fishes is called milt.
8. Songbirds live chiefly on weed seeds and insects.
9. Termites or "white ants" eat wood and destroy houses.
10. We select for house plants the type of plant which requires comparatively little light.
11. We grow many house plants, such as lilies, narcissuses, and hyacinths, from bulbs.
12. The ladybird beetle is helpful to man.
13. The most important way to conserve wild life is to protect its home.
14. The cow is the most useful all-around domestic animal.
15. The corn plant furnishes oil, sugar, starch, and fodder.
16. A hybrid is a plant or animal produced by crossing two different varieties of plants or animals.
17. Cultivating corn increases its yield from 10 to 100 times.
18. The sire is the most important animal in any herd of farm animals.
19. Grafting, which is a method of causing a branch of one tree to grow on the stem of another, is used because fruits don't breed true.
20. A hotbed, which contains fermenting manure to keep it warm, gives garden plants an early start in spring.
21. The male reproductive cell is the sperm cell.
22. The best way to get rid of flies is to destroy their breeding places.
23. A good dairy cow may give twice as much milk as a poor one.
24. The most common grass seed used for human food in this country is wheat.
25. We select the best hens by trap-nesting.
26. Dogs were probably our first domesticated animal.
27. The farm wood lot provides posts, fuel, and sometimes lumber.
28. Fertilizing soil makes better crops.
29. We improve trees by pruning or removing excess branches.
30. Large mammals are chiefly preserved in national parks.
31. When cutting a forest, some trees should be left to provide seed.
32. The mule resembles both the horse and the donkey.
33. Most hawks and owls destroy harmful rodents.
34. Contact poisons are used on insects with sucking mouth parts.

35. Ticks are removed from cattle by dipping.
36. The most harmful mammal in the United States is the rat.
37. The young chick grows for 21 days within the egg.
38. Burrowing animals can be poisoned by gas in their burrows.
39. Every plant or animal differs to some extent from every other plant and animal.
40. We put poison on plants eaten by insects with chewing mouths.

Some things to explain

1. What is meant by a perfect flower?
2. Which is more important, heredity or environment?
3. How has man upset the balance of nature?
4. Why are insects more difficult to control than are rabbits?

Some good books to read

Bush, C. D., *Nut Growers' Handbook*
Cheeseman, Evelyn, *The Growth of Living Things*
Compton's Pictured Encyclopedia
Coyle, D. C., *Our Forests*
Downing, Elliot R., *Elementary Eugenics*
Elliott, C. N., *Conservation of American Resources*
Flint, W. P. and Metcalf, C. L., *Insects: Man's Chief Competitors*
Grimes, W. E. and Holton, E. L., *Modern Agriculture*
Harwood, W. S., *New Creations in Plant Life*
Pack, C. L. and Gill, Tom, *Forests and Mankind*
Wood, A. H., *Try These Indoors*

Some interesting motion pictures

Seed Production. Gaumont British (*16 sound*)
Soybeans for Farm and Industry. International Harvester Company (*16 sound*)
How Plants Are Reproduced. Gramet (*16 silent*)
Reproduction in Plants and Lower Animals. Bell and Howell (*16 silent*)
Insect Friends and Enemies. American Museum of Natural History (*16 silent*)
Birds. (2 reels) Visual Educational Society
Where Chick Life Begins. Ralston Purina Company (*16 silent*)
Salts of the Earth. U. S. Department of Agriculture (*16 sound*)
Growing Plants Without Soil. Bell and Howell (*16 silent*)
Birds of Prey. Erpi (*16 sound*)

Courtesy Trinidad (Colo.) Chamber of Commerce

UNIT THIRTEEN

HOW IS SOLAR ENERGY CONSTANTLY CHANGING THE EARTH?

THE importance of the energy of the sun has been recognized by all races of people. Many ancient religions have been founded upon worship of the sun, and even today we have customs brought down through the ages from primitive people who worshiped the sun. But our understanding of how complete our dependence upon the sun really is has come as a result of scientific study.

It is possible that some of the earliest beginnings of science developed from man's study of the sun. There are, in the pyramids of Egypt and of Central America, and in the circle of stones left by the Druids of England, evidences that some very careful observations and calculations had been made to measure the changing seasons.

It is little wonder that primitive man sought better understanding of the sun. The floods of the Nile depended upon the changing seasons. The coming of spring meant a complete change in the manner of living for people who did not have good houses and central heating systems. Summer was perhaps the most pleasant season. The autumn season brought plentiful food, comfort, and an opportunity to prepare for winter. But for primitive man, winter must have been as difficult as it is for wild animals today.

But our debt to the sun is deeper than one of mere comfort. Our very existence depends upon it, as does the existence of the earth we call our home. Our understanding of our place in the universe is gained by study of the sun, for the sun is the only star close enough for us to know much about it.

Every part of the earth owes its present state in some way to the sun. Probably all the material of which the earth is made came from the sun at some time in the distant past. Then, as the earth cooled and took form, the energy of the sun began its ceaseless work of causing movement of the air, falling of the rain, circulation of water in the oceans, and production of other changes.

To understand how solar energy changes the earth, we must think of all the earth and not only the solid parts we see. The earth consists not only of the rocky part, or lithosphere, and the central core, or centrosphere. The liquid or water part of the earth is the hydrosphere, and the air, of course, is the atmosphere. Upon each of these the sun is constantly exerting energy which changes the earth.

1. What is the source of solar energy?

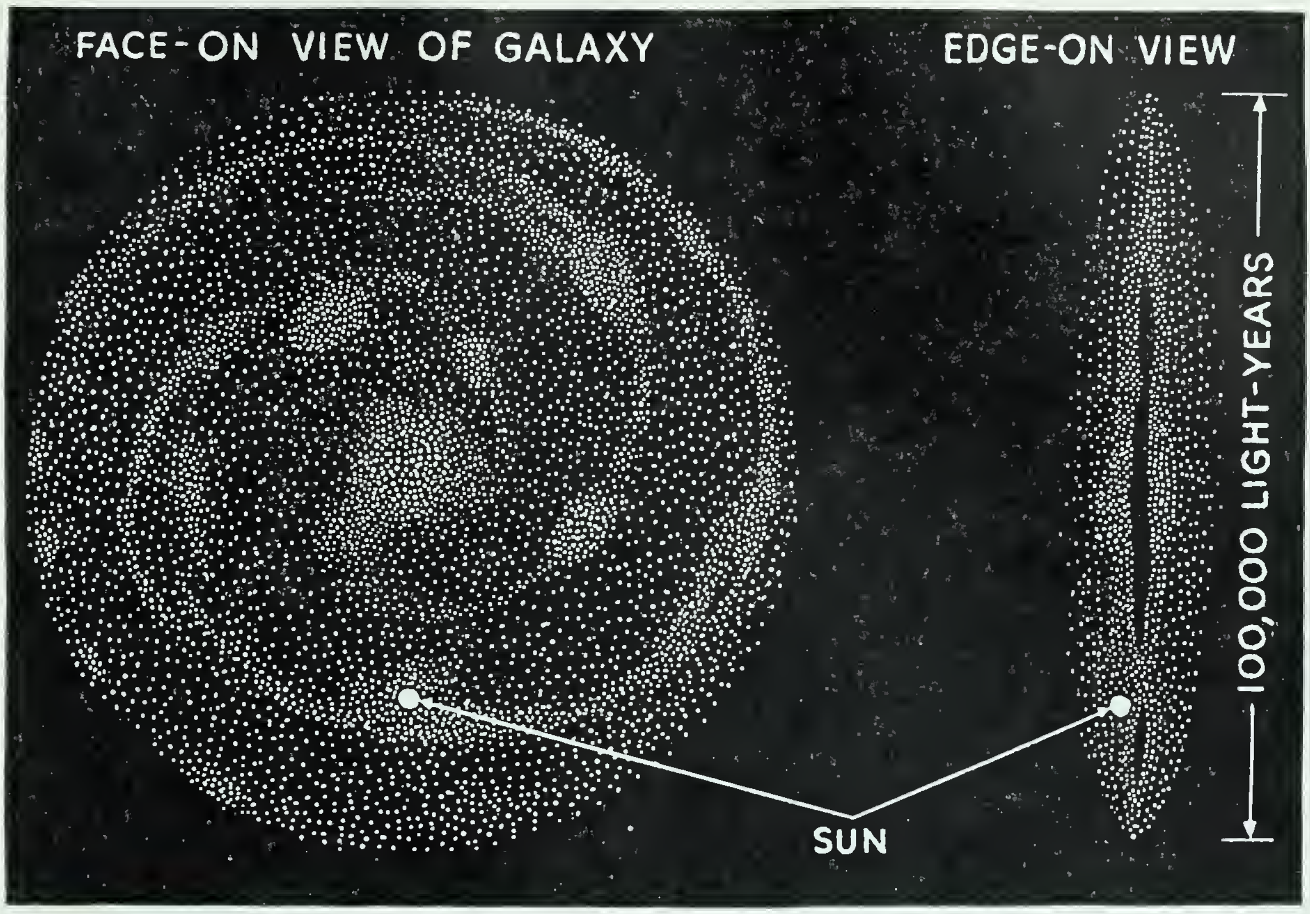
The sun, of course, is the source of solar energy. But the sun is not simply a hot object in the sky designed to give off energy to the earth. This simple explanation was believed for long centuries by ancient peoples, but today it is interesting only because it has been necessary to prove it untrue.

What is the sun's place in the universe? The sun is one of the many stars of the universe. The universe includes, in addition to the sun, all the other stars and all space. Space extends, for practical purposes, as far as there are any stars, and as far as any form of energy from any star may extend. Needless to say, we do not know whether space has any limits nor, if such limits exist, how far away they may be.

Scattered throughout the universe are many clusters of stars which, compared to the general emptiness of space, are fairly close together. These groups of stars are called galaxies. In our own galaxy, according to reasonable estimates, there are at least 30 billion stars and possibly more than 100 billion. As you know, not more than 2500 of these stars are ordinarily visible at one time. The rest can either be seen by use of powerful telescopes, or their presence can be estimated by other means. Some of these stars are very hot and blue in color, some are cooler and red, and others are of varying temperatures and colors in between. They form a group shaped roughly like a convex lens. This star system is perhaps 3000 to 10,000 light-years thick, and 30,000 to 200,000 light-years across (a light-year is six trillion miles). Looking out into space from the earth, we see part of this group of stars edgewise as the Milky Way.

At some distance from the center of our own galaxy is a star of ordinary size, of average temperature, mass, brightness, density, motion, and color—the sun. The only reason that this star is of any particular importance to us is that our lives depend upon it.

Stars vary greatly from each other in size, because some are composed of gases almost as thin as the gases remaining in a vacuum made by the usual type laboratory pump. Others are considerably denser than gold. The sun is about 1.4 times denser than water. Because of differences in density, the largest stars may be as much as 100 million times as great



This diagram provides an approximate idea of the shape of the galaxy of which the sun is a star. The sun, of course, is not the largest star but is shown large in order to locate it.

in volume as the smallest. But the heaviest stars probably do not weigh more than 100 times as much as the lightest.

The surface temperature of the sun, about 10,000 degrees Fahrenheit, is about twice as high as would be required to change all the materials found on earth into gases. It is entirely probable, then, that the materials of the sun are gases. The ordinary expectation is that these hot gases would immediately expand to form a larger star. This is exactly what would happen if the sun were not so large. As it is, its gravity is sufficient to hold these gases fairly well in place.

Where does the sun get its energy? There have been many hypotheses about the source of the sun's energy. Some have been based upon the idea that the material of the sun is on fire. Others have been based upon the idea that the sun is shrinking, and as the molecules fall inward, they give off their potential energy in the form of heat. These ideas are not sound, however.

The present theory is that the energy of the sun comes from the breaking up of atoms. As you learned in Unit Three, matter seems to be a somewhat less active form of energy.

Courtesy Yerkes Observatory

This great spiral nebula is 930,000 light-years distant. It is a galaxy composed of billions of stars.

Whenever matter is in balance, its energy is kept within the atom. But when some unusual condition exists, atoms may be broken up. This unusual condition which exists on stars and not on the earth is an enormously high temperature. For the 10,000-degree temperature of the sun is only the

temperature of the surface. Inside the sun the temperature is much higher than that.

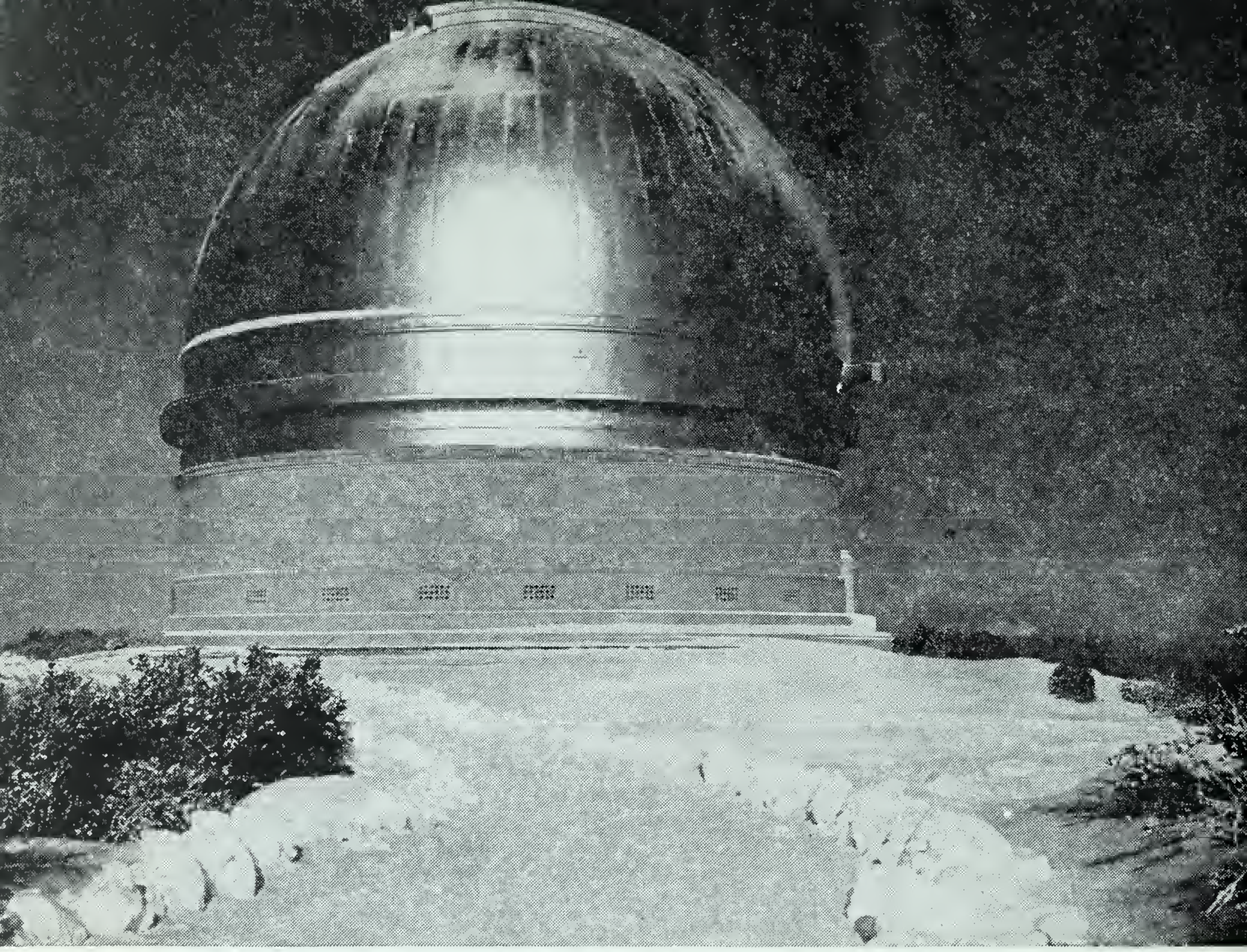
As a result of its giving off energy, the sun is gradually losing its mass. This is a matter of no immediate concern, for the process seems to have been going on for perhaps two or three billion years and will probably continue for many more billions of years before the energy of the sun becomes too small in amount to maintain the earth.

What kind of energy does the sun give off? It is probable that every type of electromagnetic radiation you have read about, from cosmic rays to radio waves, is produced by the sun. But many of these—particularly the shorter waves—do not reach the earth in amounts of which we are conscious. We are aware of the light of the sun, of the invisible but burning ultraviolet rays, and of the equally invisible but longer infrared or heat rays.

The light which strikes the upper atmosphere of the earth is not the same light which we see. The blueness of the sky shows that the blue rays are scattered by the gases and other materials of the air. The still shorter ultraviolet rays are still more scattered, so that many of them do not reach us at all. If they did, life would not exist in its present form, for some of these filtered-out, ultraviolet rays are deadly to most living things. The red and yellow light reaches the earth without much scattering, a fact which explains the yellow color of sunlight.

Is the sun a dependable source of energy? Neither the amount nor the type of energy given off by the sun is always the same. Sometimes the huge sunspots, which are cool areas (about 7000 degrees Fahrenheit), pass across the face of the sun in larger than usual numbers. During this time the sun gives off less heat and more radiation of other types. The sunspot is a severe storm of gases carrying huge electrical charges. Magnetic waves are set up as a result, and telegraph, radio, and telephone communication is upset. Yet on the average, there is amazingly little difference in the amounts of solar energy received by the earth from day to day.

We are fortunate that this is the case, for there is no other source of energy near enough to do us much good. The



Courtesy Palomar Observatory

The knowledge which we have gained concerning the universe comes from astronomical observatories. This observatory dome is mounted on a track so that the opening can be turned in any direction.

nearer stars are between four and five light-years away. But these stars, and all the other stars together, do not give us even one-thousandth as much light and heat as does the sun.

Demonstration. Do Elements Give Off Light of Different Colors?

What to use: Bunsen burner; iron wire; sandpaper; salts of copper, sodium, potassium, cobalt.

What to do: Polish the iron wire, moisten it, and dip it into one of the salts. Hold the salt in the hottest part of the flame. Observe its color. Repeat with the other salts.

What was observed: Make a table of your results.

What was learned: Answer the question at the beginning of the experiment, in so far as the evidence you have permits you to do so. How does this information help us to understand the stars?

Exercise. *Complete the following sentences:* Our own galaxy is about —1— light-years thick and about —2— light-years across. It contains about —3— stars. The big stars are made up of very thin —4—. The materials of the sun are held together by —5—. The —6— includes all stars and all space. The energy of the sun comes from breaking up of —7— because of the extreme —8— of the sun's interior. The energy we receive is in various forms of —9— radiation, particularly —10—, —11—, and —12—.

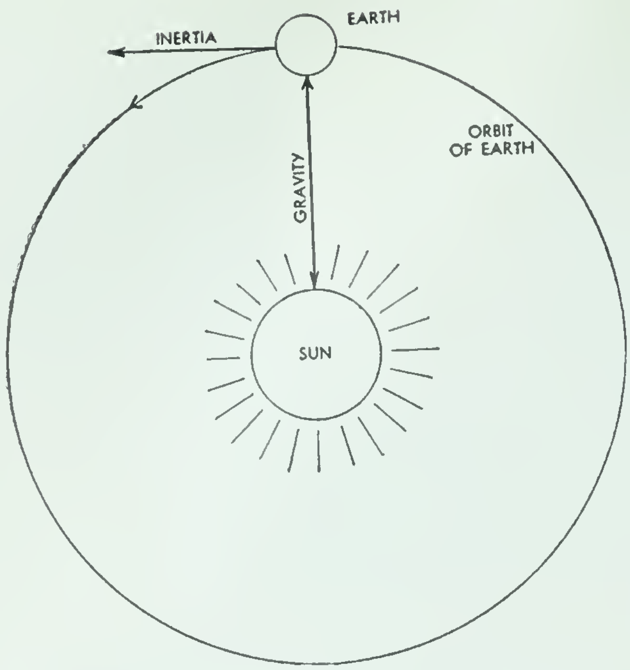
Science activity. Pick out a small space in the sky, such as the space in one of the brighter constellations, and count all the stars you can see on a clear night with the naked eye. Then with a small field glass count them again. Can you see more stars?

2. What part of the universe depends upon solar energy?

In one respect the sun seems to be an unusual star. Somehow in its long journeying through space it gathered together a group of planets, moons, comets, and smaller objects which follow it in more or less regular fashion. These objects taken together with the sun make up the solar system.

Do all planets receive equal radiation? Most of the energy of the sun passes out into space without striking any object within the solar system. The small amount that does strike the planets is dependent upon their distance from the sun and upon their size. As you know, the intensity of light or any other form of radiant energy decreases in proportion to the square of the distance. That is, since Jupiter is five times as far from the sun as is the earth, on each square foot of Jupiter there falls only one twenty-fifth as much energy as falls upon a similar area on the earth. Mercury, which is about four-tenths as far from the sun as is the earth, receives more than six times as much energy from solar radiation. Venus receives about four times as much energy as does the earth. Venus, however, is cloud-covered and reflects more of its light than does the earth, so that it retains cnly about 1.4 times as much energy as the earth's surface retains.

Mars receives radiation from the sun of less than half the intensity of that received by the earth. The "ice caps" which astronomers see on the poles of Mars may instead be dry ice, that is, solid carbon dioxide. If conditions favor life in



The orbit of the earth is not quite circular. The earth moves along the orbit because of inertia and stays in it because of the gravitation of the sun.

any part of the solar system other than on the earth, Venus and Mars are the planets on which these conditions are most likely to exist. It is not known definitely that Venus rotates at a speed to make conditions favorable for life, however. That is, days and nights might be too long for life to adjust to the great changes in temperature which would result from long exposure to the sun, followed by long periods of chilling. It is possible that the atmosphere of Venus consists of formaldehyde gas, in which case life could not exist.

Thus we see that the actual temperature of a planet's surface may depend upon factors other than its distance from the sun, which is the most important factor.

How does the sun control motion of the planets? As you already know, any object in motion continues in motion in the same straight line unless acted upon by an outside force. You know also that the planets revolve in nearly-circular orbits around the sun. It is obvious that there must be some outside force present to cause them to do this. The outside force is that of the sun's gravity.

The law of gravity is stated thus: Every body in the universe attracts every other body in proportion to its mass and inversely in proportion to the square of the distance between them. That is, the force of gravity becomes less with the distance, just as the intensity of light does.

For any object, the earth for example, to revolve in a curved path, there must be at least two forces acting at the same time. Where the planets obtained their first motion is not known, but all planets do move through space at a considerable speed. At the same time, the sun is pulling every planet toward it with a constant force. If the planets had been hanging motionless in space instead of in motion, they

would have started falling immediately toward the sun until they crashed into it.

The true explanation of the motion of the planets is centrifugal force. Recalling the familiar stone-whirled-at-the-end-of-a-string experiment, you know that the force exerted by the string must be enough to keep the stone from breaking loose, and that the speed of the stone must be enough to keep the string tight. Gravity provides the "string," and the motion of the planets provides the speed.

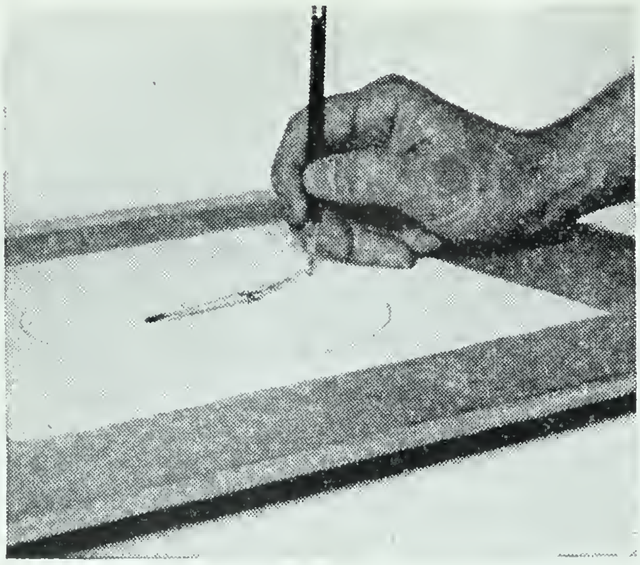
According to this law, the nearer planets are pulled with much greater force toward the sun than are the outer planets. To offset this pull, the inner planets move at much greater speeds than do the outer planets, to keep from falling into the sun. Saturn, which is about nine times farther from the sun than is the earth, travels through space at a speed only one-third as great as that of the earth.

How did the solar system originate? There are several hypotheses developed to explain the origin of the solar system.

The first of these is called the nebular hypothesis. According to this idea, a huge mass of hot gas started cooling and rotating. As it rotated, it flattened out, and most of the matter was pulled toward the center. Nine rings were formed, which eventually broke up and gathered in clusters to form the planets. Other fragments collected to form the moons, comets, and other smaller objects. This hypothesis developed from observation of spiral nebulae in space.

The next hypothesis developed around the idea that the solar system is made from materials originally in the sun. It was believed that another star in passing near the sun caused a huge tide of gases to rise from the sun's surface. One group of astronomers believed that the materials cooled to form small objects called planetesimals [plăn′ē·tĕs·ĭ·măl], which in turn were collected by gravitation into larger bodies, just as our earth collects meteorites today.

Another group of astronomers developed a hypothesis that the planets were formed directly from gases pulled from the sun by the passing star. You will find each of these three hypotheses discussed if you do much reading about astronomy. It is well to remember that a hypothesis is unproved,



A simple way to draw an ellipse, by using thumbtacks and string, is illustrated here.

and that none of these offered is likely to be a full and true explanation. About all the evidence that we can depend upon follows: (1) The solar system came into being by reorganization of matter already in existence. (2) All the parts of the solar system are made up of materials from the same general source. (3) The earth and moon passed through a completely melted stage. (4) The earth was completely formed before the sun began to act upon its surface to produce changes in the rocks.

Filmstrip: Moon, planets, comets, star clusters, nebulae. S.V.E.

Exercise. *Complete the following sentences:* The intensity of radiant energy decreases in proportion to the —1— of the —2—. Saturn, which is 9.5 times farther from the sun than is the earth, receives —3— as much energy per square foot. The planet most like the earth in temperature is Mars or —4—. The planets remain in their orbits because their —5— tends to cause them to move in straight lines, while the sun's —6— tends to pull them out-of-line. The planets —7— the sun revolve faster. The earth was once in a —8— state. The earth was —9— before weather changed its surface.

Science activity. The orbits of planets are not true circles, but ellipses. To draw an ellipse, obtain a string about a foot long. Tie it to form a loop. Push two tacks through your paper into a board. At first put the tacks two inches apart. Put the loop of string over both tacks. Then put your pencil point into the loop, pull it tight, and draw a curved line around the tacks. Move the tacks to make curves of different shapes. The location of the sun within the earth's orbit is in the position of one of the tacks. Can you explain why the distance from the sun varies?

3. What is the condition of the earth today?

For millions of years after the materials which make it up were brought together, the earth must have existed in a

melted state. It probably was surrounded by gases consisting of many elements—sulphur, chlorine, dry water vapor, and others—instead of air. The surface rocks must have glowed as lava does today in volcanoes. Probably there was much volcanic action as the surface materials cooled, settled, and remelted.

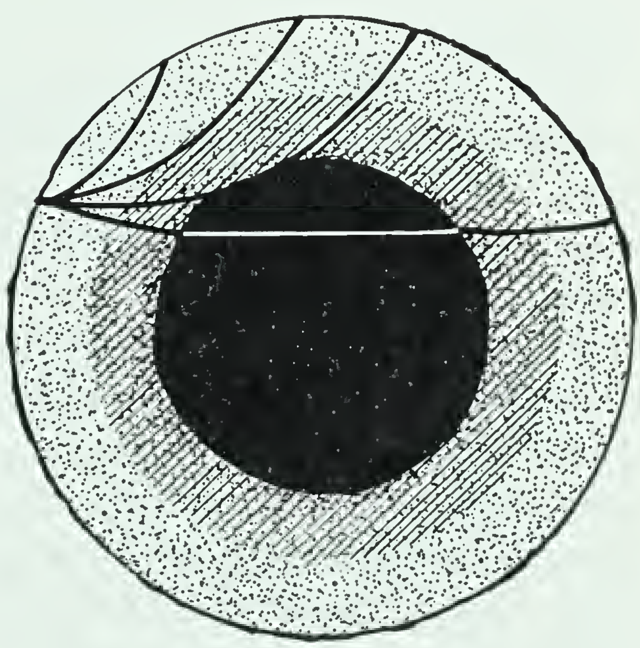
The water vapor probably formed huge clouds, high above the earth, to fall as rain which was evaporated even before it struck the hot rocks below.

After long ages, the earth gradually cooled. Minerals formed by crystallization. Rain, made acid by the gases from the air, fell upon the hot rocks, and chemical action took place to form many of the minerals which are common today. As cooling continued, volcanic action became less severe, and water ran over the surface rocks—first to form streams and lakes and eventually to form oceans. Oxygen probably combined with the surface rocks. It may seem strange, but materials can be too hot to burn or to combine with oxygen. It is possible that materials of the earth were once this hot. As more and more of the materials in near-by space were collected into the solar system, fewer meteors fell as the earth became older.

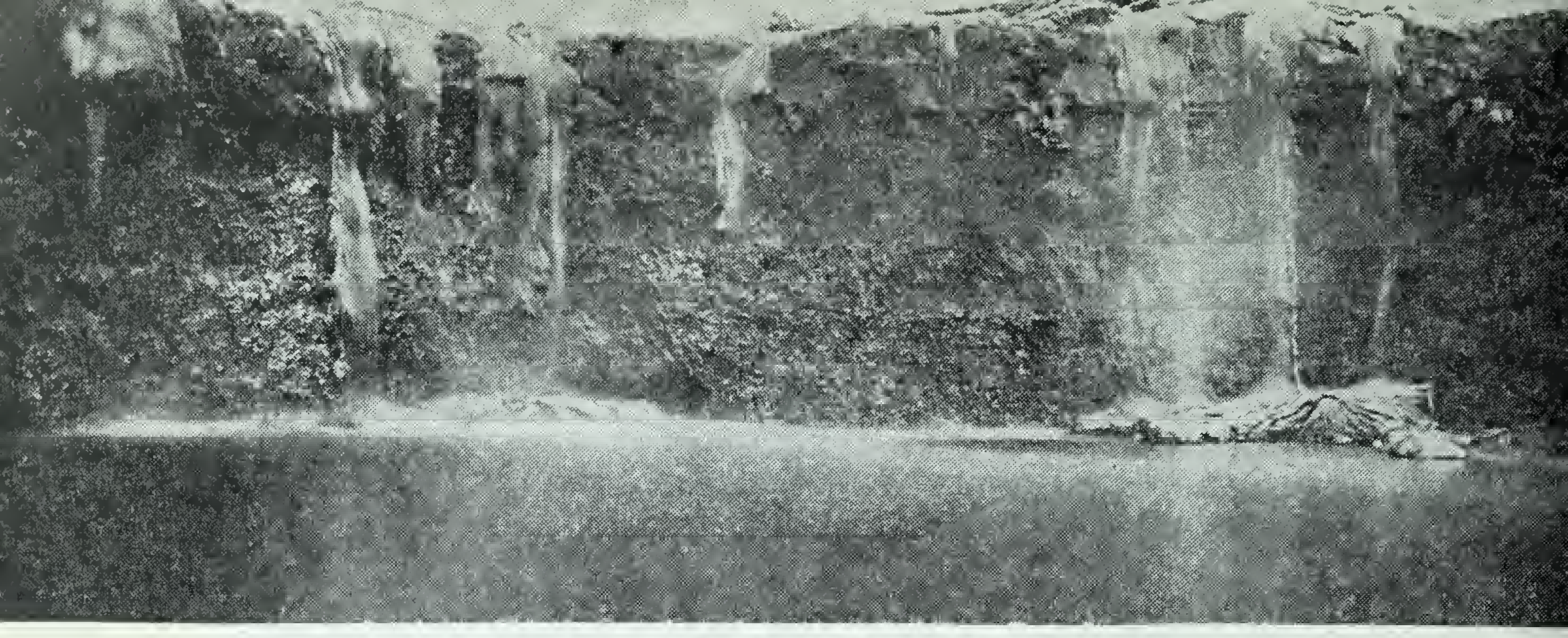
This brief story of the earth's formation is of course a hypothesis, but the hypothesis is based upon a considerable amount of observed evidence.

Is any part of the earth melted today? As you know, it is about 4000 miles to the center of the earth. It is therefore difficult to know what the inside of the earth is like. Yet careful observations make it possible to make quite accurate estimates regarding the earth's interior.

One source of information is measurement of earthquake



If the earth were equally dense throughout, earthquake waves would travel in straight lines. Instead, they travel in curves, which indicates that the rock becomes denser with depth. Can you find the four zones of rock?



Courtesy U. S. Geological Survey

When the earth was younger, lava flowed on its surface much of the time. Flows such as this one which occurred in Hawaii are rare today because the earth is comparatively cool.

waves. These waves move through different types of material at different speeds. This speed is about 3.3 miles per second in surface rocks and 4.8 miles per second in the next lower layer. As the wave spreads over the earth, accurate measurements of both the intensity of the wave and the time of its occurrence are made. The device used to measure earthquakes is called the seismograph. Measurements from various areas are compared, and the path of the wave is calculated.

Then too, the gravitational pull of the earth on the moon and on other planets is an indication of its mass, for gravitation is in proportion to mass. The force with which the earth spins is another indication of the condition of its interior.

From all these considerations it is believed that no large part of the earth is now melted. Instead, it is likely that the outer layer or the "crust" of the earth is made up of ordinary rock and is from 30 to 50 miles thick. Next is a mixture of silicates of iron and magnesium about 1000 miles in thickness. For another 800 miles this layer gradually changes from silicate rocks to a central core of nickel and iron. This central core is probably a tremendously compressed, stiff fluid. The density of the earth is about 5½ times that of water. The density of surface rocks is only 2.8 times as great as that of water, which indicates that the interior is of heavier materials than the surface.

Courtesy Trinidad (Colo.) Chamber of Commerce

The crust of the earth is made up of the lighter rocks which form mountains. The stone wall is a dike of igneous rock.

What are the types of surface rocks? Since it is believed that the earth was completely formed before any erosion took place upon it, we can expect that only the surface rocks show any evidences of such change. Even within the surface rocks it is not likely that all have been eroded.

The changes that took place as water first fell on the earth brought about a type of change unknown to the melted earth. As streams formed, they carried into low places loose fragments of ash and surface rock to form the earth's first sediments. Many materials probably dissolved in the water and were later deposited to form other sediments as the water evaporated from the hot rocks. Since there was much volcanic action, many early deposits of sediment were probably covered over completely by igneous rocks from volcanoes.

Another factor involved in formation of rocks appeared when the first forms of life developed in the oceans. Many of the algae and other simple plants and animals absorbed from the ocean water the materials needed to form skeletons and shells. Layers of rock, formed from their skeletons and shells, are thousands of feet thick, which indicates that the work of living things in rock formation is by no means unimportant.

We do not know all factors that operated to form rocks.

Courtesy U. S. Department of the Interior

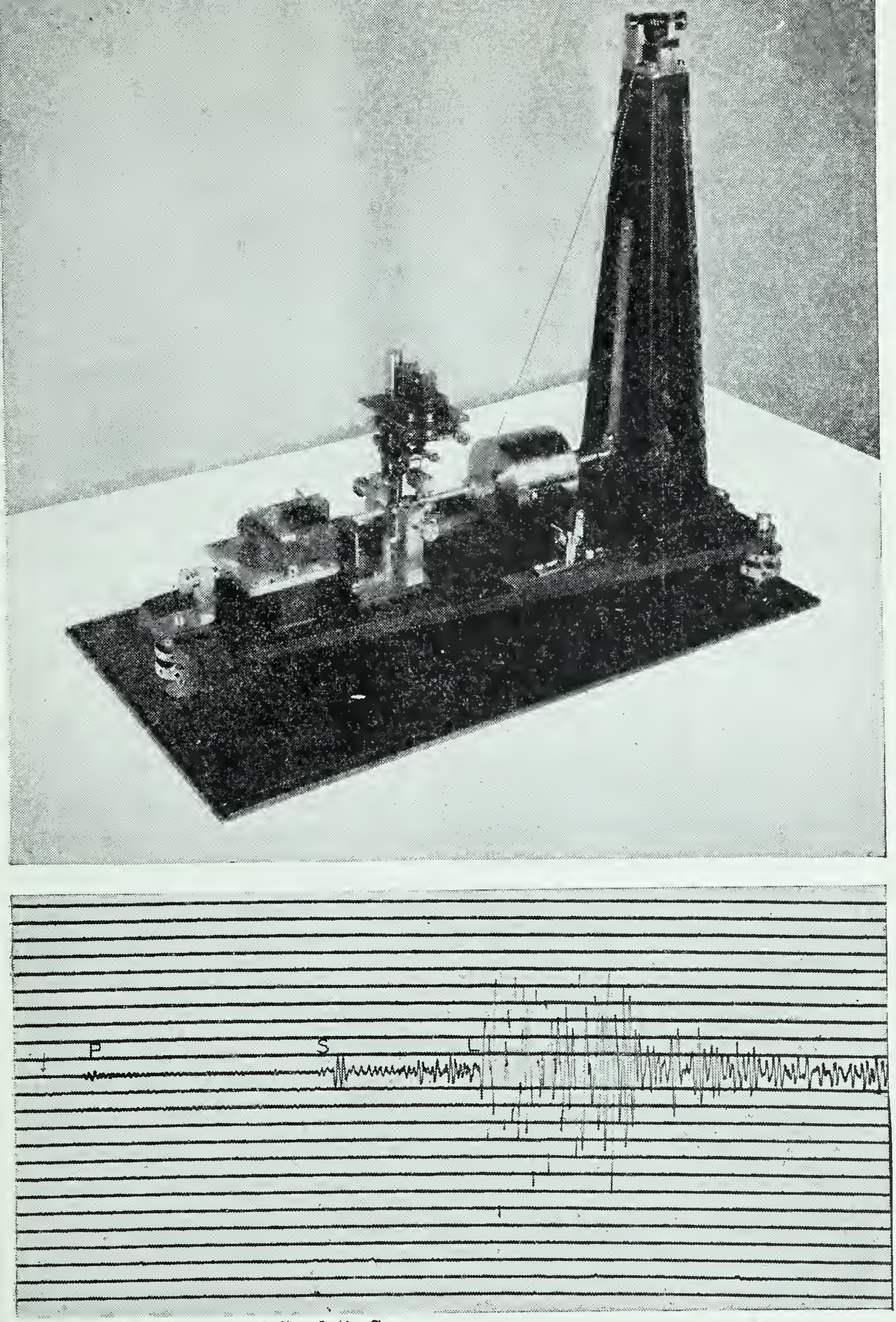
Many changes in the surface of the earth have taken place since it became fairly cool. Hot water was once a more important agent for producing changes in the earth than it is today.

There may have been forms of energy present in greater abundance in former times than at present. It is known that the radium-type compounds of today have lost a large amount of the energy they originally possessed. Although the effect of this energy upon the rocks of the earth is not known, it undoubtedly had some effect.

Some igneous and sedimentary rocks have been changed in various ways to form the metamorphic rocks which today make up the earth's crust.

What are the common rocks? In your rock collections you probably have many common rocks, and you probably are able to recognize them well enough to name many of them at sight. Yet the chemical composition of these rocks is not indicated by their names.

There are a few common minerals which occur in most rocks. The quartz rocks, of course, contain the element silicon. The feldspars contain aluminum. The basalt rocks contain iron. The limestones contain calcium. Since these elements, in combination with each other and with oxygen, form about nine-tenths of the earth's crust, you can know the nature of most rocks if you know the forms in which these elements most commonly occur. The following table summarizes most of your present knowledge about rocks and organizes it in such a way that you can see the relation between different types of rocks.



Courtesy U. S. Coast and Geodetic Survey

A seismograph (*top*) is a device for recording movement of the earth's crust. It consists essentially of a heavy weight and of devices for recording earth movement. Such a record, called a seismogram, is shown by a wavy line (*bottom*).

CHEMICAL	IGNEOUS FORM	SEDIMENT	SEDIMENTARY ROCK	METAMORPHIC ROCK
Silicon dioxide...	Quartz	Sand	Sandstone	Quartzite
Calcium carbonate.....	Tuff	Lime, shells	Limestone	Marble
Aluminum silicates.......	Feldspar	Clay	Shale	Slate
Carbon.........	Carbon dioxide, diamond	Peat	Soft coal	Hard coal
Mixtures.......	Granite	....	....	Gneiss
Mixtures.......	Basalt	....	....	Schists

To read this table, you may proceed as follows: When silicon dioxide is in igneous form it is quartz. Quartz breaks up to form sand when eroded and deposited by water. Sand is made compact to form sandstone. Sandstone under proper conditions may form quartzite.

The table makes things appear somewhat simpler than they really are. Since granite contains both feldspar and quartz, these minerals may be separated when granite is broken up, and each may form its own type of rock material thereafter. That is, both sand and shale may be products of erosion of granite. The metamorphic rocks may be broken up to form sediments, as is the case when slate weathers to form clay.

Some igneous rocks may form metamorphic rocks directly without going through intermediate stages. Careful study of this table is well worth your time, particularly if you have a rock collection.

Demonstration. How Does the Seismograph Work?

What to use: Wooden box, large weight, string, pencil, rubber bands, paper, tacks.

What to do: Stand the box on end. Inside the bottom end fasten the paper with tacks. Fasten the pencil to the weight with rubber bands. Suspend the weight inside the box so that the pencil point barely touches the paper. Suddenly jar the box.

What was observed: Describe the action of the weight when the box is jarred. Examine the paper to see what kind of mark is made on it.

What was learned: Explain how inertia causes the weight to remain in place when the box is moved. How does this demonstration indicate a method of measuring earthquakes?

Exercise. *Complete the following sentences:* The interior of the earth is probably composed of —1— and —2—. The most abundant element in the earth's crust is —3—. Rocks deposited by water are —4—; those formed by heat are —5—; and those which are changed in form are —6—. Rocks formed by animals often form —7—. Gneiss is a metamorphic form of —8—. The gas given off when acid is put on limestone is —9—. Marble consists of the chemical compound —10—.

Science activity. Arrange rocks and minerals from your collection in a form to develop the relationships shown in the table of rocks on the opposite page.

4. For how long has solar energy been acting upon the earth?

The earth is so old that it is necessary to have some sort of timetable to recognize formations of rocks which were deposited long ago. About 1800 an English geologist discovered that he could trace remnants of layers of rock from one elevation to the next by a study of fossils they contained. That is, all rocks deposited at the same time and in the same general area contain similar fossils. The use of fossils as a method of dating the rocks is now universally accepted as a satisfactory method of determining the *order* in which rocks were formed.

To estimate the *age* of the rocks, decomposition of the radioactive metal uranium is measured. Uranium decomposes to form helium and lead. Half the uranium changes to lead in about five billion years. By measuring the amount of lead and uranium in a given deposit, it is possible to know when that particular deposit was formed. To accomplish this, it is necessary to find unweathered rock, for if part of the lead or uranium is washed away, the result will not be accurate.

To explain the thousands of observations and to discuss the conclusions obtained from such studies would require a large book. As a result of these observations, the history of

Courtesy New York State Museum

The rocks themselves carry a record of how they were formed. The fossil shells in this rock give the geologist ample information for determining its history.

the earth is divided into five huge periods of time called *eras*. These in turn are further divided into shorter periods.

What was the era of most primitive life? The first era during which there was life on the earth is called the Archeozoic [är′kē·ō·zō′ĭk]. During this period, which was more than a billion years ago, the first simple living chemicals probably developed in the still pools of hot springs or in the tidal pools along some ancient sea. The simplest one-celled organisms must have started in this era. The evidence on which these hypotheses are based is rather scanty. Yet it is apparent that the general trend in development of living things is from the simple to the complex, and it is necessary to assume the simplest possible beginning to make a sensible hypothesis. We know of the existence of life in hot springs and of the existence of simple living chemicals today. How these simple living things first began life is unknown.

This primitive life was probably adapted to the soilless earth as it first cooled off—an earth of hot water, warm rains, bare rocks, and radioactivity. There are no fossils of this era.

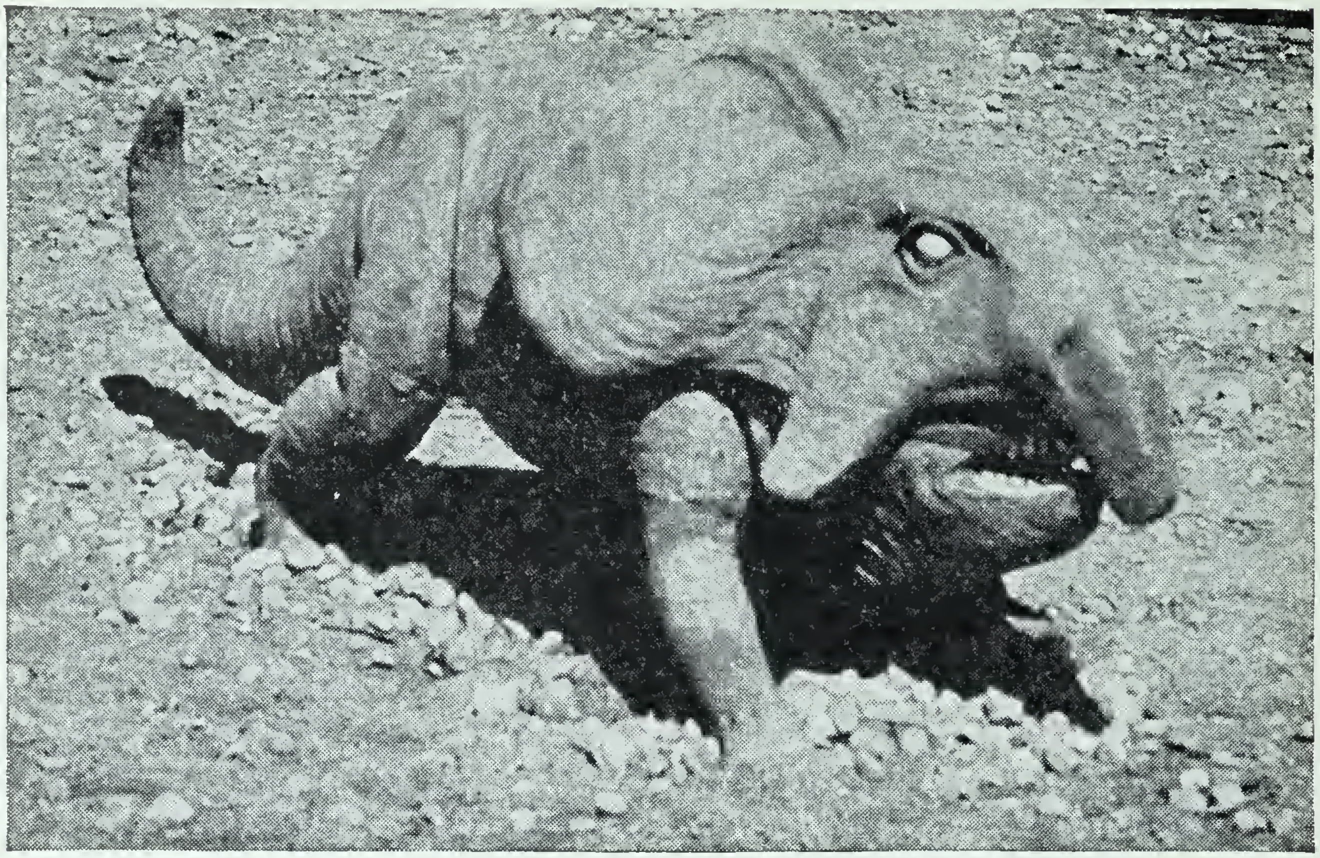
What was the era of early life? Following the Archeozoic era was a period during which life was adapted to an earth that still was far from ready for complex life. It was called the Proterozoic [prŏt′ẽr·ō·zō′ĭk], or "era of early life." This early life developed about a billion years ago and continued until about 490 million years ago, according to the best estimate that can be made on present knowledge. The first living things to develop in this era were probably simple algae. Huge amounts of limestone rock known to be of the type deposited by algae are found in rocks of this era. There are also found large deposits of carbon believed to have been formed by these simple algae.

What fossils indicate the era of ancient life? During the era of ancient life, the Paleozoic [pā′lē·ō·zō′ĭk], living things developed which left behind easily-identified fossils. This era marked a turning point in the development of life on the earth. Many living things by this time had developed hard tissues, such as shells and skeletons, which were readily preserved in rocks. Many entire specimens have been found, so that knowledge of this era is rather complete.

During the paleozoic era many forms of life now common on the earth appeared. Among them are the simple plants —such as mosses, horsetails, and ferns—and such animals as worms, crabs, starfishes, insects, and mollusks. Toward the end of this period, which lasted 300 million years, the first fishes and amphibians appeared.

By careful study of fossils, it is quite possible to date the rocks of this era with a fair degree of accuracy.

What fossils indicate the era of intermediate life? Less than 200 million years ago Mesozoic [mĕs′ō·zō′ĭk] life began. During this age of intermediate life the climate was warm and life was abundant. This was the age of the huge reptiles of which the dinosaurs [dī′nō·sôr] are best known. These lizard-like animals, some tiny and some giants, were stupid and cold-blooded. They were not capable of changing as the era drew to a close, for the amount of food eventually decreased as the climate became cooler.



Courtesy Sinclair Refining Co.

This big-nosed reptile, one of the dinosaurs, lived in the period of intermediate life. The one shown here is only a model. This dinosaur was about as big as a pig.

During the latter part of this period the simplest mammals appeared, living perhaps on plants, on the eggs of the dinosaurs, and upon insects. Birds gradually developed from reptile-like forms. It is highly probable that any rock containing a fossil of a bird is not more than 100 million years old.

At the same time, the common flowering plants were first appearing upon the earth, and cone-bearing trees were common.

What changes accompany recent life? Recent life appeared upon the earth about 60 million years ago. Of course there have been many changes during this time, but the animals that have existed since the beginning of this era can be compared to those we see today. This period is called the Cenozoic [sē′nō̇·zō′ĭk] and is thought of as the age of mammals. Grasses reached their present highly developed state. Songbirds became common. It is believed that man has lived upon the earth for the last million years of this era.

What changes of the earth mark the different eras? The earth's crust is marked by two distinct formations: huge ridges which form the continents and huge basins which form

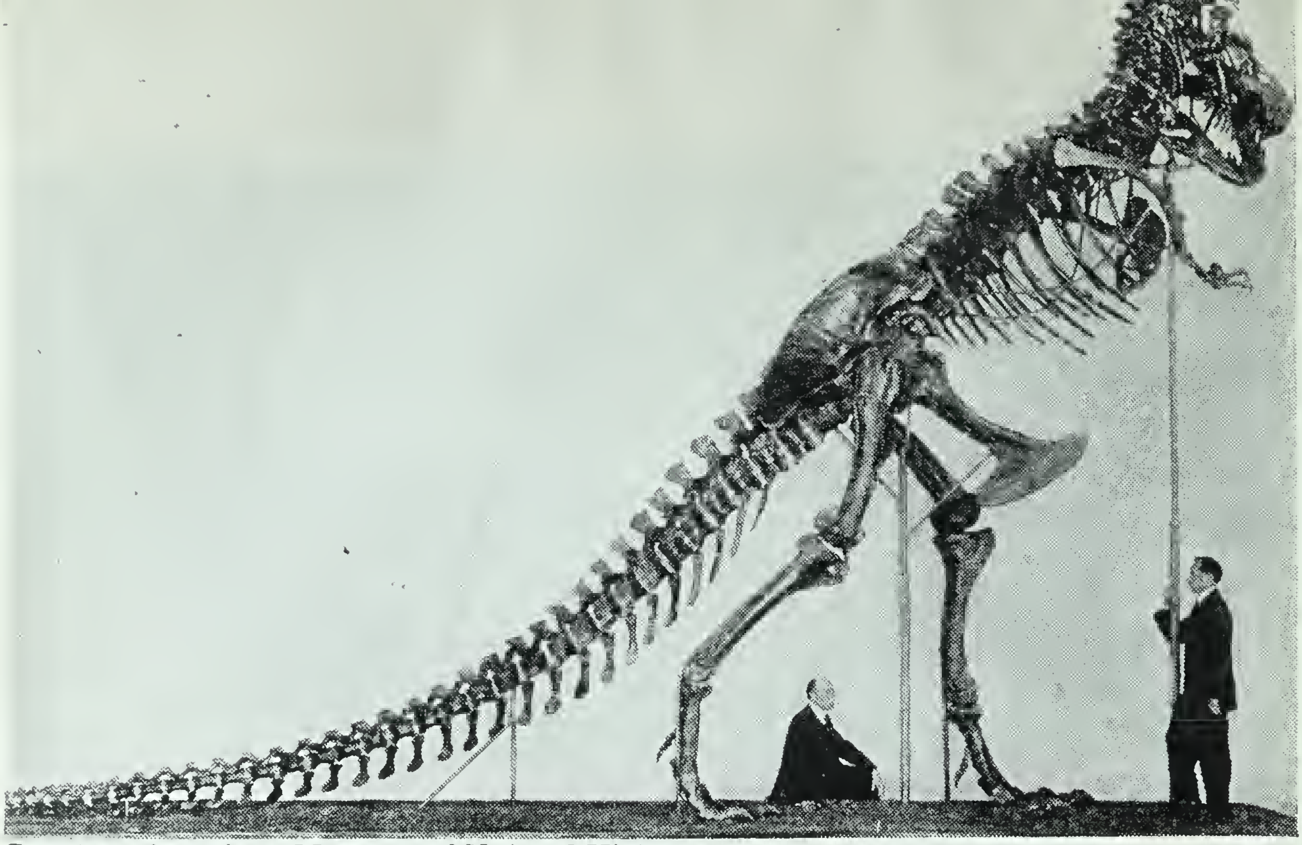
the oceans. It seems probable that the ocean deeps have never been land. But there have been many changes in the levels of the continents. At different times there have been shallow seas where there are now mountains, and where once mountains existed there are now lowlands. Each of the five eras is marked by a rather striking shift in the elevation of portions of the continental ridges. The complete story of these changes must be left for your college courses or for outside reading.

Yet we know from this brief story that the earth has within it a dependable calendar, shown in the table below, by which we can date changes caused by solar energy and by the changing surface of the earth.

NAME OF ERA	HOW MANY YEARS AGO DID IT START	CHIEF NEW PLANTS	CHIEF NEW ANIMALS
Cenozoic (recent)	60 million	Seed plants, as grasses, flowering plants, and trees	Man, other mammals; birds
Mesozoic (intermediate)	190 million	Cone-bearing trees, cycads; simple flowering plants	Reptiles, as dinosaurs and turtles; small mammals and birds
Paleozoic (ancient)	490 million	Ferns; horsetails; mosses; club mosses	Amphibians; fishes; mollusks; insects; spiders; crabs; starfish; true worms
Proterozoic (early)	More than a billion	Algae	Simple, many-celled animals
Archeozoic (most primitive)	Two or three billion	One-celled forms	Many-celled forms

How do scientists study ancient life? Our knowledge of ancient life is derived almost entirely from fossils. Fossils are remains or imprints of living things.

The most valuable fossils are those which are found whole. Some corals and sponges are found with only the soft parts missing. Bones of the larger animals are excellent fossils for study. Insects trapped in amber, a fossil tree gum, have



Courtesy American Museum of Natural History

The most fierce of the dinosaurs—Tyrannosaurus Rex, king of tyrants —is only a mounted skeleton today. This giant reptile lived entirely on flesh.

been preserved for millions of years. In petrified wood, tissues have been replaced with stone, so that the pattern is left. Some animals have been trapped and preserved in the tar traps in Los Angeles and in Trinidad. In dry desert air animals have been so well preserved from decay that an actual specimen of a dinosaur's skin has been found. Mammoths that lived thousands of years ago have been found frozen in glacial ice in such perfect preservation that their flesh was fit to eat when found.

Leaves have fallen into mud and left behind mud prints. Animals have left tracks showing their footprints so clearly that it is possible to pour plaster of Paris in the fossil track and have a model of the animal's foot. Tracks made by animals dragging their bodies through the mud have been found. Many fossil shells of clams, snails, and oysters are found.

Some animals built tunnels or dug holes or in other ways left evidences of their work that the observing can interpret today.

However, most of the fossils have been destroyed because of the great changes that have taken place in the earth's surface. Running water, glaciers, and volcanoes destroy

bones and flesh far more readily than they do solid rock. Since most animals are of delicate structure, few leave fossils. The bones of birds are especially porous and light, and are easily crushed. Few fossils of man have been found. As a result, our knowledge of the earth's history is far from complete

Demonstration. What Are Fossils?

What to use: Functional collection—fossils.

What to do: Using the information which accompanies the collection of fossils, learn what the different types of fossils are.

What was observed: Draw sketches of two or three fossils, and write notes as to their formation.

What was learned: List as many kinds of fossils as you can.

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* hypothesis, fossils, one-celled, insects, worms, reptiles, mammals, flowers, ferns, seed plants, recent, early, most primitive, intermediate, ancient, era, order.

5. Why are there variations in solar energy?

Before we can understand the effects of solar energy upon the constantly changing surface of the earth, it is necessary for us to understand the causes and some of the effects of variations in the amount of energy falling on the earth. Some of these causes are well known, while others are hardly guessed at with any degree of confidence.

How does the angle of the sun's rays cause variations in solar energy? As you know, the greatest amount of radiant energy is absorbed by a surface at right angles to the rays. As the angle becomes less, the amount of energy falling upon a unit of area also becomes less.

There are three factors which determine the angle of the sun's rays at any given place at a given instant. These are the latitude, the time of day, and the season. To a very minor extent the slope of the land may be considered a fourth factor. At any instant there can be but one point on the earth's surface where the sun is directly overhead. This point receives the greatest amount of energy from the sun.

The latitude of a given place determines the average amount of solar energy which falls upon it compared to places

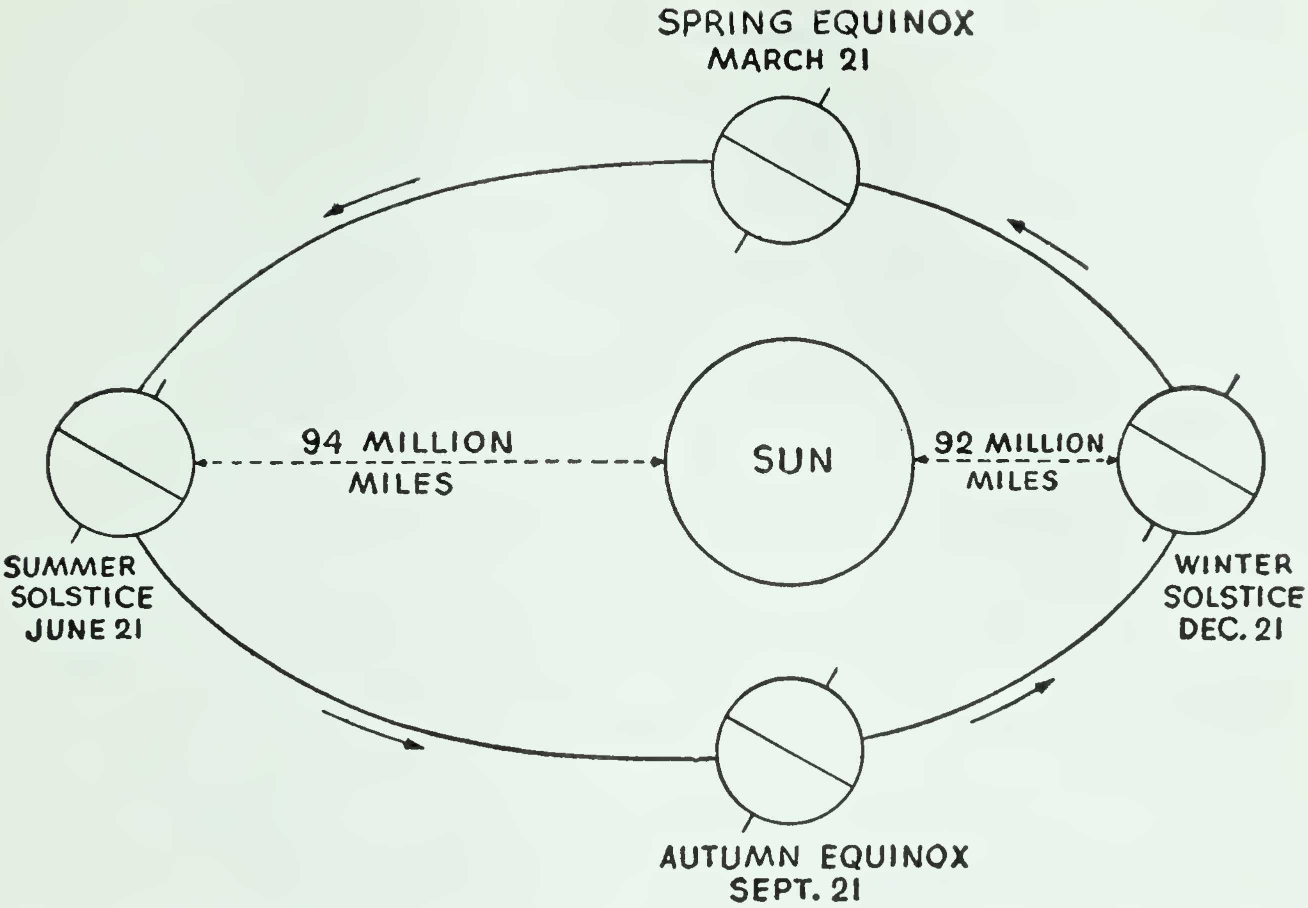
farther north or farther south. It is estimated that at the poles only 38 per cent as much solar energy falls during the year as at the equator. At latitude 60 degrees the amount of solar energy is about 58 per cent of that falling on the equator. At latitude 40 degrees (which is the latitude of southern Pennsylvania) the earth receives 79 per cent as much energy as falls at the equator. At latitude 20 the amount of energy is 94 per cent as much as that of equatorial regions.

During part of each year the polar regions receive no solar radiation at all. For, as you know, the earth's axis is inclined at an angle of 23½ degrees from the perpendicular. As the earth revolves around the sun, first one pole and then the other is inclined away from the sun. Except for a few moments on March 21 and on September 22, one pole is always in darkness. On the other hand, each pole in turn is inclined toward the sun during its summer season and receives considerable amounts of solar energy during this time.

The matter of the earth's rotation and inclination affect the length of day and night. Although only one-half the earth can be lighted at any one time, inclination and rotation cause the days to be long in the summer months and short in the winter months. Thus there are greater differences in temperature at a given place than there would be if days and nights were always of the same length.

Does our distance from the sun make a difference in temperature? As you know, the distance from the sun to the earth is about two million miles greater in northern summer than in winter. This makes our winters shorter and warmer and our summers shorter and cooler than they would otherwise be. It is estimated that the northern winters may average as much as six degrees Fahrenheit warmer than they would be if we had winter when the earth was farthest from the sun.

Does the earth always absorb solar energy equally? The amount of insolation (energy from the sun) received during any given day depends in part upon the amount that is reflected back into space and upon the distance over which the heat is scattered. It is estimated that more than a third of the energy which might fall on the earth is reflected before it ever reaches the ground.



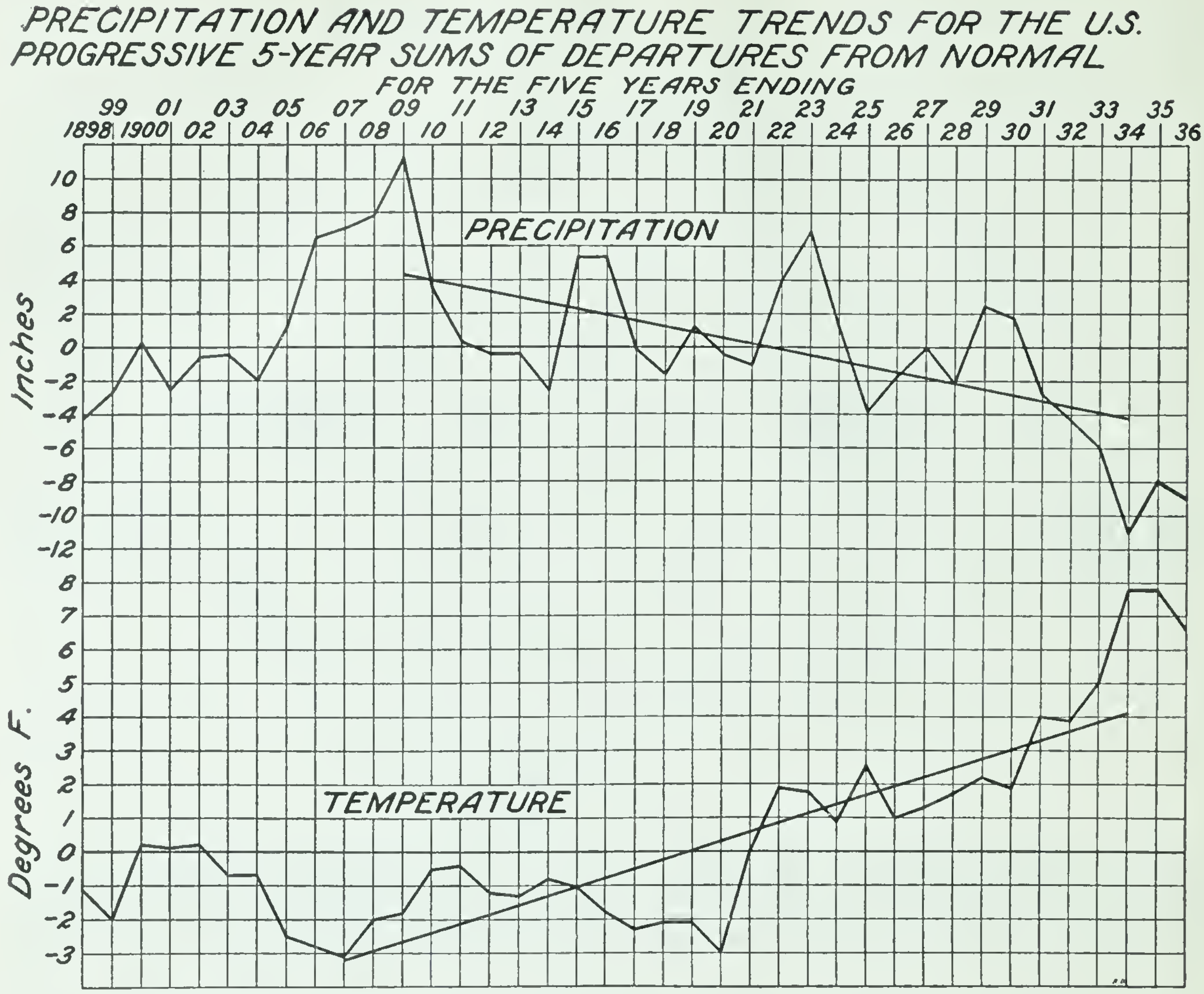
The changing angle of the axis of the earth in relation to the sun is the chief cause of the marked seasonal changes in temperature. The off-center position of the sun is greatly exaggerated in this drawing.

The chief reflectors of insolation are clouds. It is a common experience to note the cooling effect of a cloud passing over the sun on a partly cloudy day. Volcanic dust also affects heat absorption, but it is not known exactly what the effect is.

The type of surface on which solar energy falls also affects its ability to absorb heat. Ice, sand, black soil, grass sod, and forests each absorb varying amounts of heat, causing considerable local differences in temperature, even though the sun may be shining equally upon all.

Does the sun always give off the same amount of energy? It has been impossible to observe the sun for a long enough time to know whether it varies greatly in brightness from one million-year period to another. But it is known that sunspots make a difference in the amount of heat the sun gives off. When sunspots are most abundant, it is estimated that the loss of heat is about 2 per cent of what would normally fall if there were no sunspots. This difference is enough to cause rainy seasons when there are many sunspots.

Are there long-time changes in earth temperature? One



Courtesy U. S. Weather Bureau

From 1908 to 1934 the temperature of the United States increased and the amount of rainfall decreased. This comparatively short period is insufficient to indicate a permanent trend.

of the great unexplained mysteries of the earth is what causes the changes in temperature which permit it to go through long periods of glaciation. These have occurred since the earliest eras. There have been four of these periods in quite recent times. The first occurred about a million years ago and lasted perhaps 50,000 years. The second occurred about 750,000 years ago and lasted about 100,000 years. The third began about 350,000 years ago; and the fourth and most recent began about 125,000 years ago. Like the second, these two glaciers each lasted about 100,000 years. That is, the most recent glacier began to grow noticeably smaller only 25,000 years ago. There still remain five million cubic miles of ice around the North and South Poles.

If we add together the glacial ages, it is seen that the four glaciers together lasted about 350,000 years. During the last

million years the earth has had large glaciers for about one-third of the time.

Several theories have been advanced to explain the formation of glaciers. One that seems reasonable is that volcanic dust in the air may cause changes in temperature sufficient to make deposits of ice possible, for rather slight changes in temperature cause considerable differences in climate. It is well known that after volcanic explosions of the type which fill the air with dust, winters are colder and summers are shorter. Yet this knowledge is not enough to prove the case. In order that glaciers may form, there must be heat enough to continue evaporation of water from the oceans, or no snow would fall. It is not absolutely certain, in fact, that glaciation is not caused by unusual warm periods instead of unusually cold ones.

How are tree rings used to show variations in climate? Variations in climate can be estimated by studying tree rings. The thickness of the annual rings of growth of trees corresponds quite closely to the suitability of growing conditions of a given year. To measure these rings, thin slices are cut from the stem of a tree and their images projected upon a screen to enlarge them. The differences in thickness of the rings indicate differences in climate. Since some trees are hundreds of years old, it is possible to trace climate far into the past. Then by matching rings with ancient wood samples, it is possible to continue the history still farther.

The present indication is that the earth is growing somewhat warmer and drier than it was a few hundred years ago.

Do all parts of the earth hold heat equally well? As you know, the temperature of land and water differ, although both may be at the same latitude and receive the same amount of insolation. Water, because it holds several times as much heat as an equal weight of rock, warms and cools more slowly than does the earth.

Although clouds reduce the amount of heat reaching the earth, they also reduce the rate of heat loss. As you have observed, the earth cools more rapidly on a clear night than on a cloudy night. Heat losses at night from deserts are much greater than from the moist farm lands of the Middle West.

Courtesy Glacier National Park

Many glaciers that remain upon the earth today are left over from the recent Ice Age which lasted until about 25,000 years ago. The coldness of high altitudes causes mountain glaciers to melt more slowly than glaciers on lowlands.

Mountainous regions lose heat rapidly because they are protected by only a thin layer of air, and as a result radiation of heat into space is more rapid than it is in lower regions.

Demonstration. Does Water Hold More Heat Than Iron Does?

What to use: Balance, beakers, piece of sheet iron, burner, thermometer.

What to do: Cut a strip of sheet iron, and roll it to a size that will fit easily in a beaker. Weigh the iron. Put the iron in a beaker of water, and bring the water to a boil. Prepare two beakers of cold water, already weighed and with the temperature measured. Put the iron in one beaker. In the other pour boiling water equal in weight to iron. Measure the temperatures of the beakers as soon as they have reached a stable temperature.

What was observed: Multiply the weight of the water in the second beaker by the increase in temperature caused by the iron. Multiply the weight of the water in the third beaker by the weight of the increase in temperature caused by the water. Divide your first product by the second.

What was learned: How does the amount of heat held by water

compare to the amount held by iron? What errors did you leave uncorrected in your experiment?

Filmstrip: Continental ice sheet. S.V.E. Spencer.

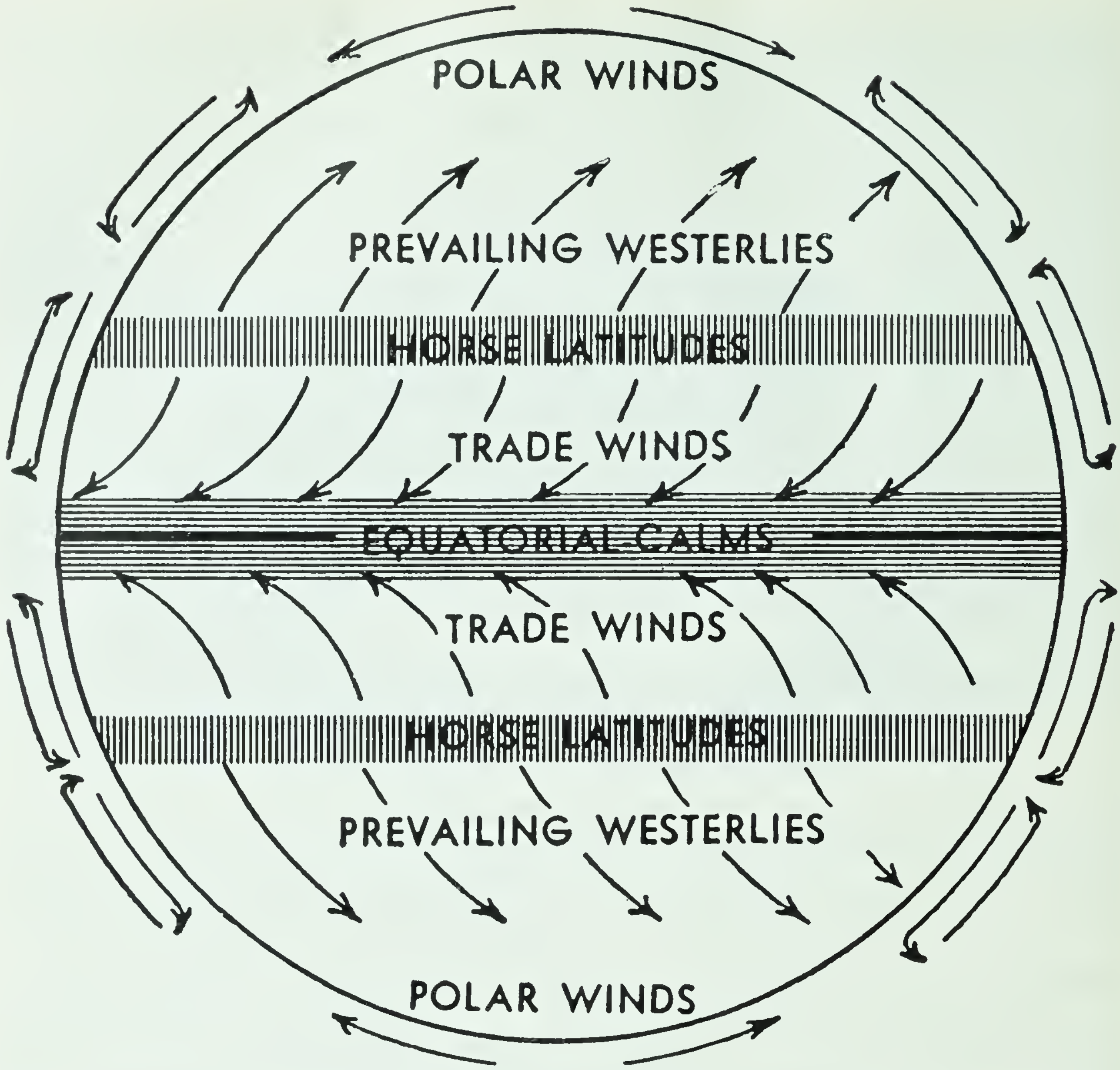
Exercise. *Complete the following sentences:* Three factors affecting the angle of the sun's rays on the earth are —1—, —2—, and —3—. The exposure of the earth to the rays of the sun is called —4—. The amount of solar energy falling on the earth at latitude 50 is probably about —5— per cent as much as at the equator. The winters of the southern hemisphere are —6— than they would be if the earth were always equally distant from the sun. The earth absorbs about —7— of the insolation it receives. The —8— of the sun reduce the amount of insolation. The first of the four recent glaciers appeared about —9— years ago, and the most recent began to disappear about —10— years ago.

6. How does solar energy cause air movement?

If there were no variations of temperature from place to place, there would be little movement of the air. There would be a gentle east wind caused by the rotation of the earth, and some movement in an up-and-down direction as the air warmed and cooled. Otherwise the air would be calm.

What causes winds to blow? When the air is heated, either directly by insolation or indirectly by contact with warm earth, it expands. When air is cooled, it contracts and becomes more dense—that is, it becomes heavier per unit of volume.

Because air is a fluid, it may move from one place to another. The direction of movement is determined by the air pressure, which in turn is dependent upon the density of the air. Cold air exerts greater pressure upon the earth than does warm air. Pressure may be measured by use of the mercury barometer, which is ordinarily a J-shaped tube. The long arm is closed, the short arm open. The tube is filled with mercury in such a way that the upper part of the long arm contains a vacuum. Air pressure upon the mercury in the open arm supports a column of mercury about 30 inches high at sea level. This column of mercury exerts 14.7 pounds of pressure per square inch upon the bottom of the tube, which is exactly balanced by the air pressure of 14.7 pounds per square inch in the open arm.



The winds of the world are broken up into clearly defined belts. Study this diagram to locate the areas of high and low pressure.

The pressure may also be measured by the aneroid barometer, which contains a hollow disk of springy steel. The disk contains a partial vacuum. Changes in air pressure upon the sides of the disk cause it to expand or contract. The moving sides of the disk operate levers which move the indicating needle.

The cause of winds, then, is differences in pressure, which in turn are the result of differences in temperature.

How does air circulate upon the earth? There are many systems of circulation of the air upon the earth. The greatest system, the one which includes all others, is called the world wind system. This wind system is divided into five belts. Starting at either pole and going toward the equator, they are the polar winds, the prevailing westerlies, the horse lat-

itudes, the trade winds, and the belt of calms. The general movement of the winds in each belt is shown in the diagram.

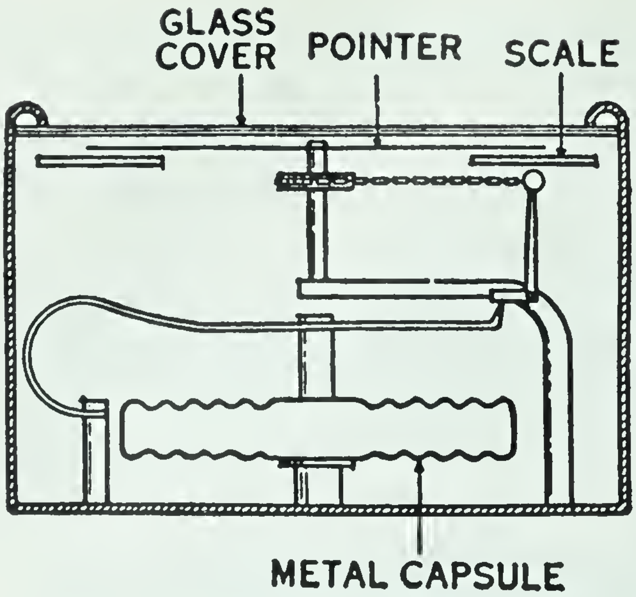
As you can see, the general movement of the winds along the ground is from the poles to the equator. That is, the cold air of polar regions is heavier than the air of warmer regions and forces its way along by pushing the warmer air aside and upward. There are two factors which complicate this general pole-to-equator air movement. One, of course, is the rotation of the earth. The winds of the trade-wind belt blow from the east, and those of the prevailing westerly belt blow from the west because of rotation.

The other factor complicating wind movement is not so simple. As you can readily see, the winds from the two poles meet at the equator, forcing huge masses of hot, moist air upward. The resulting upward movement cools the air, and heavy rains fall in the belt of calms. When the rising winds cool, they start their return to the poles, constantly losing heat because of their altitude and because of expansion. By the time these upper, returning winds have reached a latitude of 30 degrees, they have cooled enough to be denser than the air which is moving along the ground.

Consequently the movement in the horse latitudes is downward. Some of this down-flowing, cold, heavy air spreads southward, some northward. That which moves northward forms the prevailing westerly belt. As the cold air falls, it begins to increase in temperature and to absorb water from the earth. This drying effect produces the deserts of Mexico and our own Southwest, the Sahara, and the Australian deserts.

The prevailing westerly belt includes two conflicting sets of winds: the cold winds moving toward the equator from the poles and other cold winds moving from the horse latitudes toward the poles.

Air movement in the prevailing westerly belt is complex. Huge masses of air tend to break away from the world system and to move in this zone without mixing with near-by masses of air. The polar type air masses are cold, drying, and bring clear weather. The anticyclones are polar air masses. The warm air masses may form wherever any mass of air has been in contact with the earth or, more particu-



The aneroid barometer is the most convenient device used for measuring air pressure. The pressure upon the springy sides of the metal capsule causes it to vary in thickness. The levers show the amount of change in terms of air pressure.

larly, in contact with the ocean, until it has become warm and moist. These warm masses bring high humidity. The cold air masses tend constantly to force or pry the warm masses of air up from the surface. In general the cold air masses move across the United States from the Northwest, while the warm air masses move inward from the Gulf or from the Pacific, coming from the Southwest.

Most changes in weather result from the coming of one or the other types of air mass.

What causes local winds? There are many local variations in temperature. These in turn cause differences in air pressure. Hot air is frequently moist and rises rapidly when it forms in a region of general high pressure. The resulting upsweeping winds may cause thunderstorms or tornadoes, depending upon the velocity the air attains and the amount of cooling that takes place. In general, thunderstorms are larger and less violent than tornadoes. The two may occur at the same time in near-by regions, or either may occur alone. Wind velocity in thunderstorms is generally moderate, usually not exceeding 35 miles per hour along the ground. The velocity of wind in tornadoes may approach 500 miles per hour in the whirling funnel.

How can we judge wind velocity? While the velocity of the wind can best be measured by an anemometer, it is not always practical to make a direct measurement. The table on page 756 indicates a helpful relationship between the wind and its effects.

The average wind in the United States is a fresh wind, while a high wind occurs only occasionally in storms. Gales and hurricanes are rare.

Bottom left, courtesy U. S. Weather Bureau

The wind velocity and other information regarding the condition of the upper air is recorded by devices carried aloft by balloons. The velocity of winds may be determined from observed effects. In the pictures at the top and at the bottom right, which effect was produced by a tornado? Which by a high wind?

KIND OF WIND	VELOCITY (Mi. per hr.)	VISIBLE EFFECTS
Light breeze . . .	2–5	Moves leaves of trees
Fresh wind	5–15	Moves branches of trees; blows up dust
Brisk wind	15–25	Sways branches; makes whitecaps on water
High wind	25–35	Sways trees; blows twigs from ground
Gale	35–75	Breaks branches; blows bricks from chimneys
Hurricane	75–100	Uproots trees; destroys houses

How does air movement equalize temperature? The constant flow of wind from cold to warm regions has a tendency to equalize temperatures in different parts of the world. This effect is definitely noticeable along shores of lakes. In the daytime the cool air lying over the lake tends to flow outward toward the warmer land, while in the evening a cool land breeze tends to flow out over the lake, which holds its heat better than does the land. A similar equalization of temperature takes place on a world-wide scale.

DEMONSTRATION. HOW DOES THE MERCURY BAROMETER WORK?

What to use: Short-stemmed thistle tube, barometer tube, rubber tube, glass L tube, one-hole stopper to fit thistle tube, two other stoppers, ring stand and clamps, mercury, meter stick.

What to do: Connect the thistle tube and barometer tube with a short rubber tube. Pour the mercury into the thistle tube, filling the tubes until the thistle funnel is about one-third full. Tap to remove all air bubbles from both tubes. Then set up the apparatus as shown in the picture on the opposite page. Measure the height of the mercury in the long tube above the level of the mercury in the open tube. With the mouth withdraw air and blow air into the thistle tube.

What was observed: What is the normal air pressure in inches of mercury? How does changing the pressure affect the height of the mercury?

What was learned: How does the barometer work?

Filmstrip: Oceans, world currents, winds. S.V.E. Spencer.

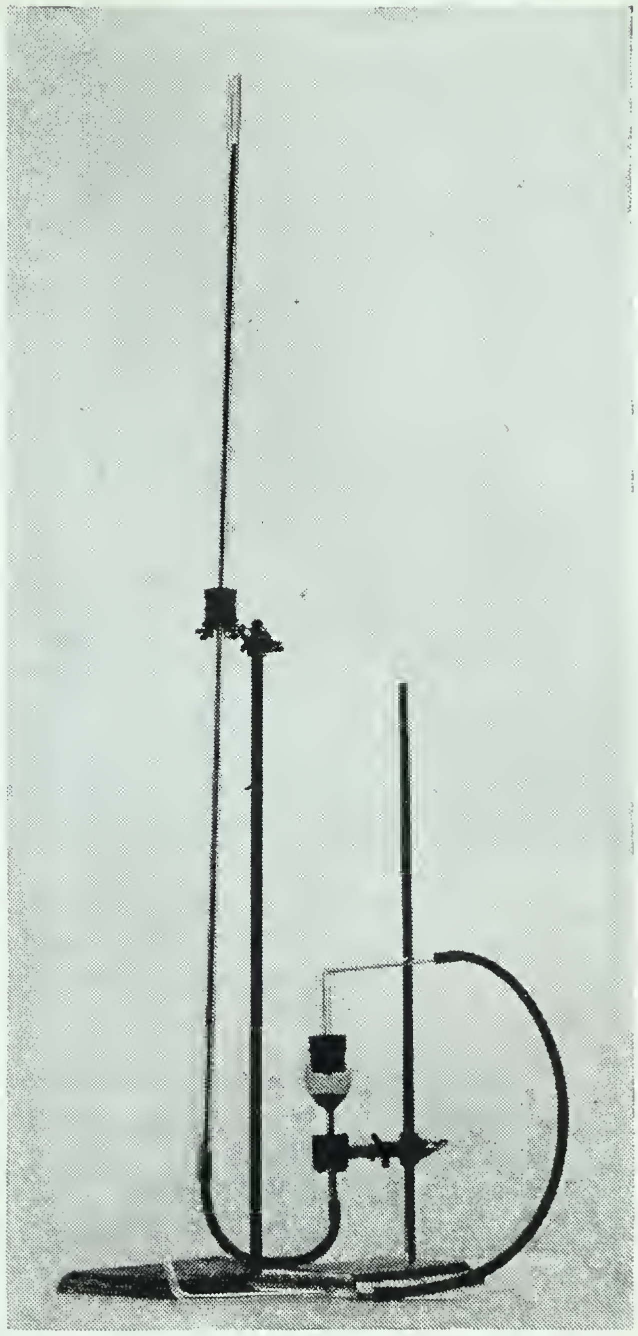
Exercise. *Write a paragraph summarizing this problem, using in it the following words:* trades, westerlies, high pressure, low pressure, horse latitudes, calms, tornado, thunderstorm, polar winds, cold, warm. *Draw a diagram of the world wind system to illustrate your paragraph.*

Science activities. 1) Which direction does the water rotate in flowing from the bathtub? How does this question relate to the wind system?

2) Make and display a set of weather flags. They should be exactly like those displayed by the Weather Bureau.

7. How does solar energy cause the water cycle?

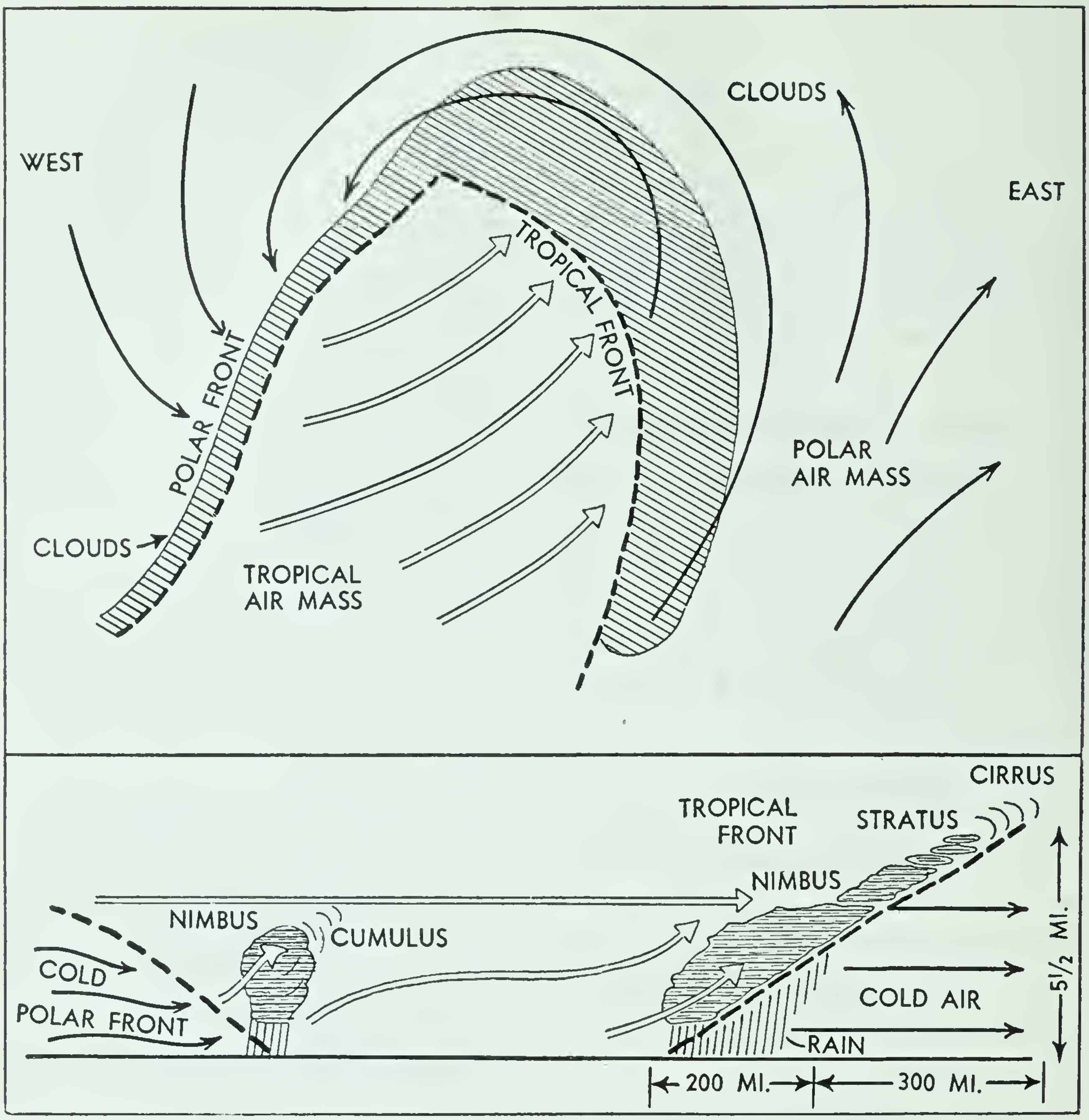
You have already learned that the water cycle is the change of water to a gas and the change of the gas back to water, which goes on constantly under natural conditions. This never-ending cycle is perhaps as important as any other in changing the surface of the earth. It is also one of the most noticeable of the changes that takes place in the atmosphere.



With this demonstration barometer you can show by blowing or withdrawing air with the mouth how changes in air pressure change the height of the mercury in the barometer.

What causes evaporation and condensation? Wherever water is found in the presence of heat, it evaporates. The rate of evaporation of water from the ocean and from the land depends directly upon the amount of solar energy available. It is estimated that there is enough heat available in the Southwest to evaporate 90 to 100 inches of water yearly. In the New England states the amount of heat available will evaporate only 20 to 30 inches of water.

When water vapor cools, it condenses—that is, it changes back to liquid water. Water usually condenses on some solid object—an electrically charged particle of dust or smoke in



Adapted from J. Bjerknes

The more violent storms occur where a tropical air mass encounters a polar air mass. The wedging effect of cold air causes the warm air to rise, with resulting condensation of water vapor. The approaching storm is heralded by cirrus clouds, then come the stratus clouds, and finally the nimbus, or rain, clouds. What clouds are seen on the cold front? The white arrows indicate warm winds, the black arrows cold winds.

the air—or upon some cold surface, such as a windowpane.

Most condensation occurs in clouds. Tiny droplets form, which fall slowly toward the earth. They remain in the air only if they are lifted by rising currents of air. Often droplets of water at the bottom of the cloud may settle into warmer air and be re-evaporated, while other droplets form at the top of the cloud. If a cloud is formed in contact with the earth, it is called fog.

The rays of the setting sun illuminate the high cirrus clouds, while the lower cumulus clouds are almost completely in darkness. Four hours after this photograph was taken, a thunderstorm occurred. The following day, rain fell steadily.

There are four types of clouds: nimbus, stratus, cumulus, and cirrus. In summer all are composed of water droplets except the cirrus which is usually made up of ice crystals. Clouds may be given names consisting of two parts. For example, since rain falls from nimbus clouds, a cumulus cloud, or thundercloud, from which rain falls is named cumulo-nimbus. Most cloud names are made up of combinations of the names of the four basic forms of clouds.

The characteristics of the four types of clouds follow:

KIND OF CLOUD	AVERAGE HEIGHT AT BOTTOM	APPEARANCE AND EFFECT
Cirrus	2–7 miles	Thin, white, and feathery. Indicates rain
Stratus	500–1000 ft.	In layers, flat and gray. Precedes rain
Nimbus	3000 ft.	Dark, covers sky. Rain falls
Cumulus	2000 ft.	High-piled and rolling. Thunderclouds

Water may fall from clouds in any of four forms. If the drops collect at temperatures above freezing, rain falls. If the droplets collect as crystals, they form snowflakes. If

raindrops are formed but freeze, the result is sleet. If raindrops freeze and are tossed up and down by violent winds in cumulus clouds, they condense ice layers around the original raindrop and fall as hail.

Water evaporates from the soil at all times. When the air is still and cool, the vapor may condense immediately to form dew. The formation of dew is of considerable importance, for it provides needed moisture for plants and animals. Where the temperature of the air is below freezing and the ground is still fairly warm, water vapor may condense in crystals to form frost.

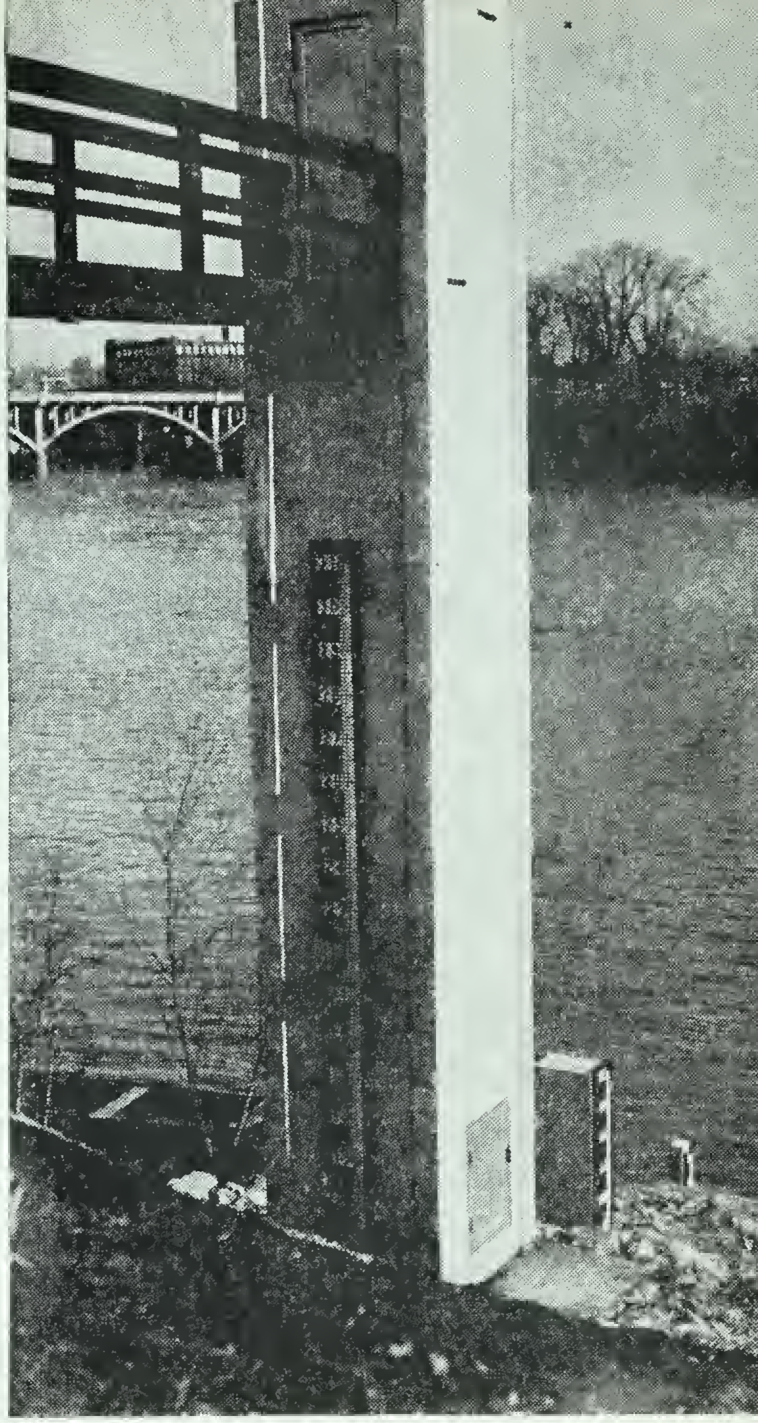
Where does water vapor condense? Wherever a wind carrying water vapor is forced to rise, condensation takes place. There are two reasons for this result. In the first place, upper air is cool because of altitude. Then too, as air rises to regions of lower pressure, it expands, and the expansion causes cooling.

Most rainstorms in the United States occur where the warm and cold air masses meet. The advancing edge of the cold air mass (called a cold front) pushes its way beneath the warm air mass. Along the cold front the amount of rain is likely to be small, and the rain gives way to clear weather.

But as the warm air mass advances, the warm front is pushed up and above the cold air mass for a considerable distance. As the warm front continues its advance, first cirrus, then stratus, and finally nimbus clouds form. Rain is likely to occur at the approach of the nimbus clouds. During the entire time required for the passage of the warm air mass, nimbus clouds are likely to be seen, and rain may occur as the warm air rises and cools.

You will recall that air is cooled as it passes over mountains, and rain falls upon the windward (toward the wind) side of the mountains. The wind falling down the leeward (away from the wind) side is becoming warmer, and no rain is likely to fall. About two-thirds of the United States is affected to some extent by the influence of mountains on rainfall.

The air at the equator is constantly rising because of the pressure of the north and south trade winds. The air in this region can move only upward. The torrential downpours of



Right, courtesy U. S. Weather Bureau

The height of water in rivers affects power production, transportation, water supply, and safety. The river gauge at the right measures the height of the water in the river.

rains common to the tropics result from the constant cooling of the vapor-laden trade winds. As the belt of calms follows the sun north, the belt of equatorial rains moves with it. Then when the sun is overhead in the southern hemisphere, the belt of rains follows it there. As a result, places near the equator have two rainy seasons a year, while those near either tropic have only one.

What causes variations in humidity? Air is dry in two situations. Where an air mass or wind has its beginning over land, it is likely to be dry because of an insufficient amount of water available to make it humid. And when a cool air mass is warmed rather rapidly, it will be dry because of its greatly increased ability to absorb water. You know that an increase in temperature of 20 degrees doubles the capacity of air to hold water vapor. Air falling from high elevations is almost always dry.

Air is humid when it has been in contact with warm, moist land for some time, or when it has blown inland from a body of warm water, such as the Gulf of Mexico. Air is also humid when its ability to hold water vapor has been decreased by cooling. Air rising to higher altitudes is almost always humid.

How does the water cycle affect temperature? Evaporations of water results from the absorption of heat (about 540

calories of heat per gram). When the water vapor condenses, all this heat is given off. Consequently, the water cycle constantly transfers heat from the point where water evaporates to the point where the vapor condenses. A snowfall actually warms the air in the region of the cloud where the vapor condenses and the water freezes. The practical warming effect of this condition is summed up in the observation, "It'll have to warm up to snow." Actually, the formation of snow may cause the warming.

Demonstration. How Does Cooling Cause Clouds to Form?

What to use: Flask, pressure air pump, one-hole stopper, ring stand and clamp, glass and rubber tubing, rubber band, alcohol.

What to do: Pour a tablespoonful of alcohol in the flask. Put a glass tube in the stopper. Put the stopper in the flask, and warm it, shaking the flask to wet the sides. After five minutes fasten the flask firmly on the ring stand. Attach the stopper loosely to the flask or clamp with the rubber band. Connect the pump, and pump air into the flask until the stopper blows out. The rubber band will prevent it from flying into the room.

What was observed: Watch closely for the formation of the cloud as the stopper blows out.

What was learned: Relate these ideas to the demonstration: Expansion causes cooling; cooling causes condensation.

Filmstrip: Clouds. Pickwell.

Exercise. *Complete the following sentences:* Slow changing of water to a gas is —1—. It has a —2— effect upon the surrounding area. As air becomes warmer, it can —3— more water. Rain falls from —4— clouds. The thunderhead is a —5— cloud. —6— is produced near the ground when moist air strikes a cold region. The western states have unequal rainfall on account of the —7—. Rainfall is heaviest on the —8— side of mountains. Rain falls at the equator because the air is —9—. Heavy rains often fall along a —10— front.

Science activity. Make a booklet of pictures of storms. Label each picture correctly.

8. How does solar energy cause weathering?

Weathering is the process which causes changes in the make-up of the rocks and soil. The chemical composition may

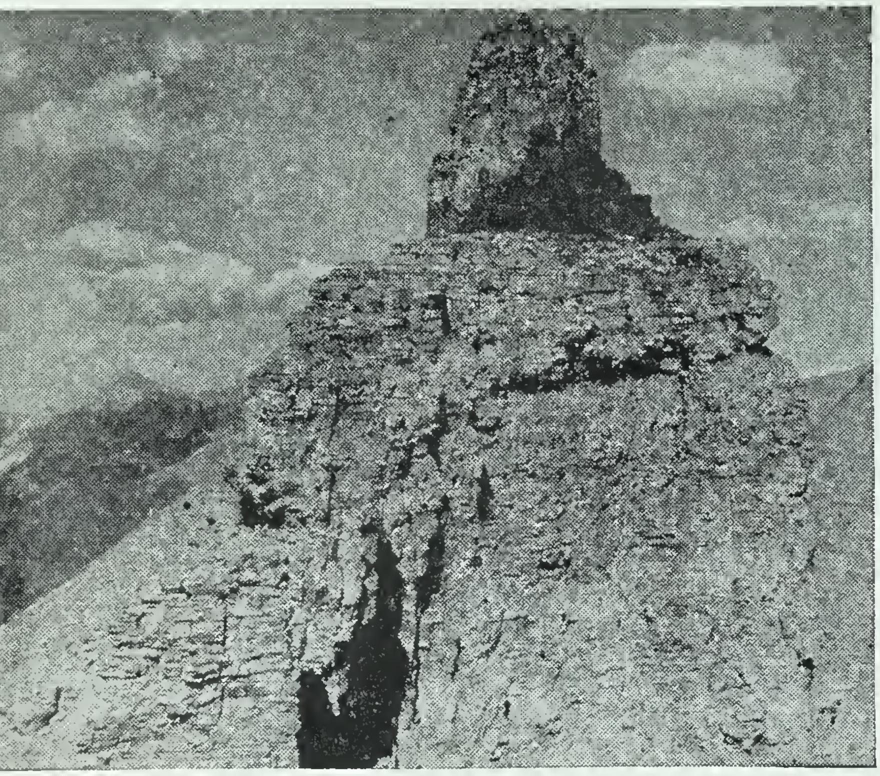
Courtesy U. S. Geological Survey.
Photos by G. K. Gilbert

Rocks weather in different ways. The rounded granite rock (*left*) weathered by expansion and contraction; the limestone rock weathered by solution along the cracks in it.

be altered by weathering, or the rocks and soil particles may be broken into smaller pieces. There are many agents which cause weathering. These are chemical agents, mechanical agents, and living agents. And, of course, all changes depend upon a supply of energy, which is obtained from sunlight.

What are chemical agents of weathering? You are thoroughly familiar with the most active of chemical weathering agents—oxygen. It is probable that most of the oxidation of surface rocks took place long ago, for the rocks now are approximately half oxygen by weight. There is still some oxidation going on, however, as fresh rock surfaces are exposed. Carbonation is the process of materials reacting chemically with carbon dioxide to form carbonates. Hydration is the combination of materials with water to form hydroxides (bases resulting from combination of a metal and oxygen).

The water vapor in the air and water in the soil are of great importance in weathering. Many materials that will scarcely combine chemically at all when dry react rapidly when wet. Iron rusts many times more rapidly in the presence of water. Carbon dioxide in water forms a weak acid (carbonic acid) which dissolves limestone rock readily. This weak acid will combine with a number of rocks to form chemicals soluble in water. Thus chemical weathering is much more rapid in humid than in desert regions.



Courtesy Glacier National Park

Entire mountains may be decomposed by weathering. Freezing and thawing and contraction and expansion are the chief agents acting upon exposed mountain peaks.

Water and air entering rocks through deep cracks caused by earthquakes or other large forces may weather rocks for considerable distances into the earth.

What are mechanical agents of weathering? Mechanical agents of weathering are those forces which act to break or move rocks.

The most important of the mechanical weathering agents are expansion and contraction, resulting from heating and cooling. Because most rocks are poor conductors, the outer layers become quite hot, while the inner portions are still cool. The outer layers thus become loosened and either chip off or peel off in layers. Added to this is the fact that rocks are usually made up of mixtures of minerals which have different rates of expansion. The greater the changes of temperature in a short period of time, the greater is the effect of such changes. High mountains may be littered with huge boulders, broken loose from the bedrock (solid earth rocks) by the effects of temperature changes. Granite hills eventually have a rounded, domelike appearance as boulders break off.

Another type of mechanical weathering results when water freezes in cracks in rocks. A cubic foot of water makes about 1.1 cubic feet of ice. The expansion which results from freezing is capable of producing tremendous forces, which wedge the rocks apart in a most effective manner. Great slabs and blocks of rock may be loosened from cliffs and mountainsides to crash into the valleys below. Breaking off a huge piece of rock exposes new surfaces upon which the many weathering agents may act.

When water enters porous rocks and freezes, the cemented particles are loosened to such an extent that the rock may crumble in the hand. Sandstones in particular are weathered in this way.

The effect of gravity upon rocks tends to break them into smaller fragments as they fall and roll.

Related to both chemical and mechanical weathering is solution. When cracks are formed by any cause in rocks along the edge of a cliff, stone may be loosened by a combination of freezing and going into solution until the crack is greatly widened. The stone along the edge of the cliff may be left standing in pillars and columns. This effect is often noted along limestone cliffs.

Courtesy U. S. Department of Agriculture

At any point on the surface the depth of the soil is not great. Usually the depth of fertile soil is less than a foot, while the depth of soil of any type is only a few feet.

Columns formed by mechanical cracking must not be confused with the basalt columns which develop into huge six-sided blocks as a result of processes of crystallization. These columns apparently form as the melted stone cools. Basalt weathers much more slowly than do the more porous, softer limestones, shales, and sandstones.

How do living things weather the soil? Living things often combine both chemical and mechanical action at one time in their attacks upon the earth's crust. When a tree root forces its way into a crack in the rock, chemicals present in the fluids in the root hair speed up solution. At the same time the wedging action of the expanding root opens the crack wider.

Earthworms carry soil particles to the surface, and as they

do so digest humus (vegetable matter) which exists in the soil. The digestive juices attack rock particles to some extent. The burrows of earthworms open the soil to attack by air and water.

When birds peck gravel to fill their gizzards, they are acting as weathering agents. For as food is made finer by passing between the rough stones in the grinding process, the stones are worn smooth by friction and by the action of digestive juices.

Lichens grow upon the surface of rocks and have considerable effect in formation of soil. It is possible that lichens were among the first living weathering agents to appear upon the earth. Their action upon the rocks seems to be chemical.

How does weathering result in soil formation? Compared to the thickness of other layers of the earth, the layer of soil is of almost no importance as far as mass is concerned. But from the viewpoint of living things, the soil is the most important of all. For without soil, life upon the land could not exist as we know it today. In general the thickness of soil is not more than a foot. In some wind-deposited hills, and in some valley bottoms composed of soil deposited by water, the depth may range from 10 to 50 feet, but such depth of soil is most unusual. It is more than offset by the large areas of bare, exposed rock where no soil exists.

Soil which remains where it is formed is called residual [rē·zĭd′ū·ăl] soil. Residual soil is likely to be black and mixed with leaf mold and other types of humus at the top. At a depth of two to four inches the soil becomes coarser grained, including broken rock particles mixed with roots and crumbling soil particles. Below this level there is a zone through which the rock particles become increasingly large, while the proportion of soil and humus becomes increasingly small. These conditions may be found to exist in old forests where no erosion has taken place for many years. Residual prairie soils are usually deeper, more fertile, and of better texture than forest soils. Grass roots break the soil more thoroughly and form a better type of humus than do tree roots.

Soil which has been moved from its place of origin by any

means is called transported soil. The chief transported soil is that carried by water and settled out as the currents were slowed or as the water evaporated or sank into the earth. Soil in the northern states has been transported by glaciers and consists of mixed sand, clay, gravel, and traces of many materials. Soil in the western states is transported by wind. Soil may be transported by gravity alone.

Courtesy U. S. Geological Survey

Everywhere that soil is found plants take part in its formation. This process is particularly noticeable in swamps, where the masses of vegetation make up a thick cover of the soil.

The sediments, sand, clay, and weathered limestone form the chief materials of most soils. Mixed into these soils are many organic materials, both plant and animal. A soil without some humus or organic matter is of such poor quality that few plants will grow upon it. An excellent soil must have more than one of these materials in order to support plants.

Demonstration. What Are Some Properties of Soil?

What to use: Soil samples, lamp chimneys, cloth, rubber bands, pan, microscope, crucible, burner, ring stand, balance, if available.

What to do: Put samples of sand, clay, and humus, into lamp chimneys closed at the bottom with cloth held in place with rubber bands. Weigh each. Stand the lamp chimneys in a pan of water. Observe which absorbs the water fastest. When the samples are saturated, again weigh each lamp chimney.

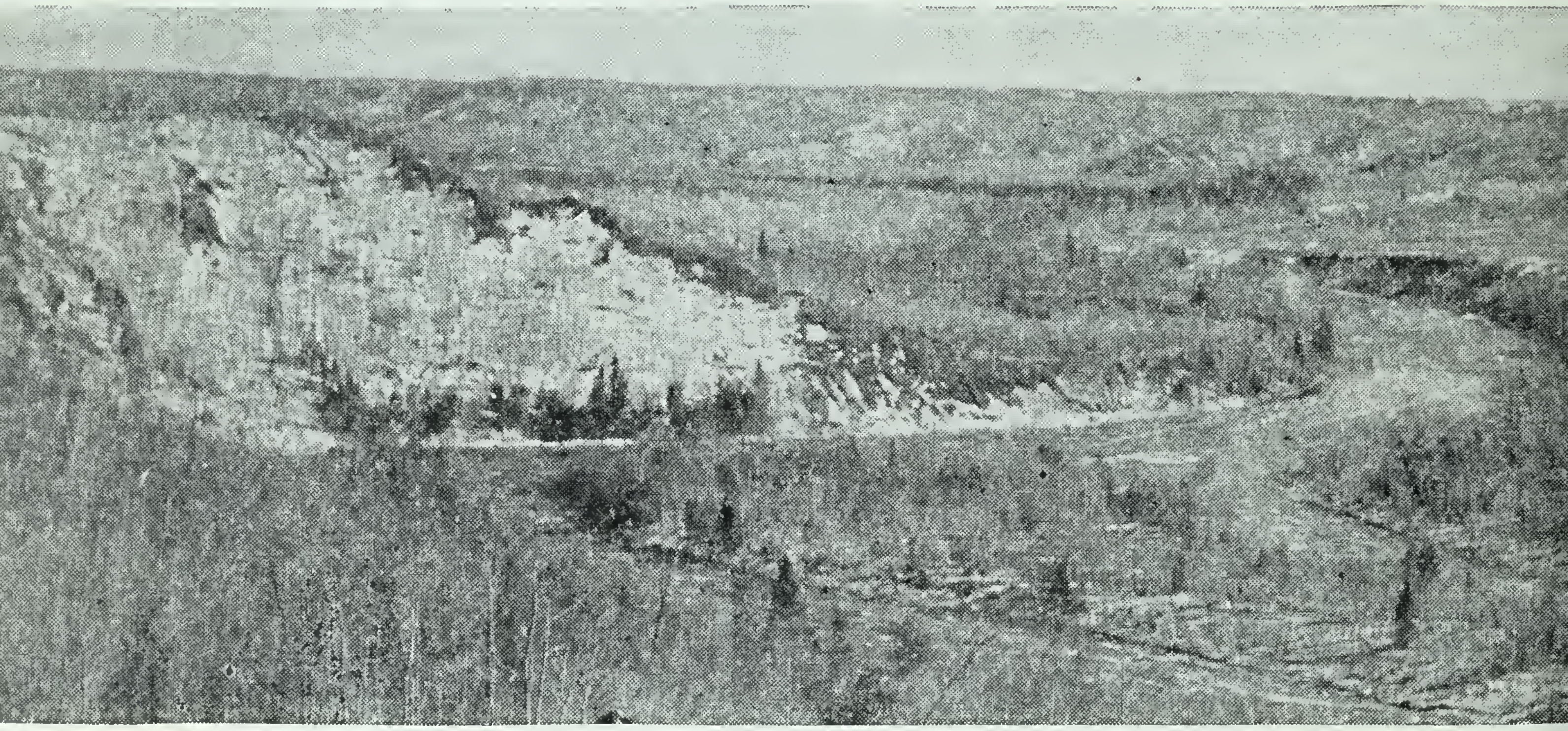
Put samples of the soil under the microscope and observe them.

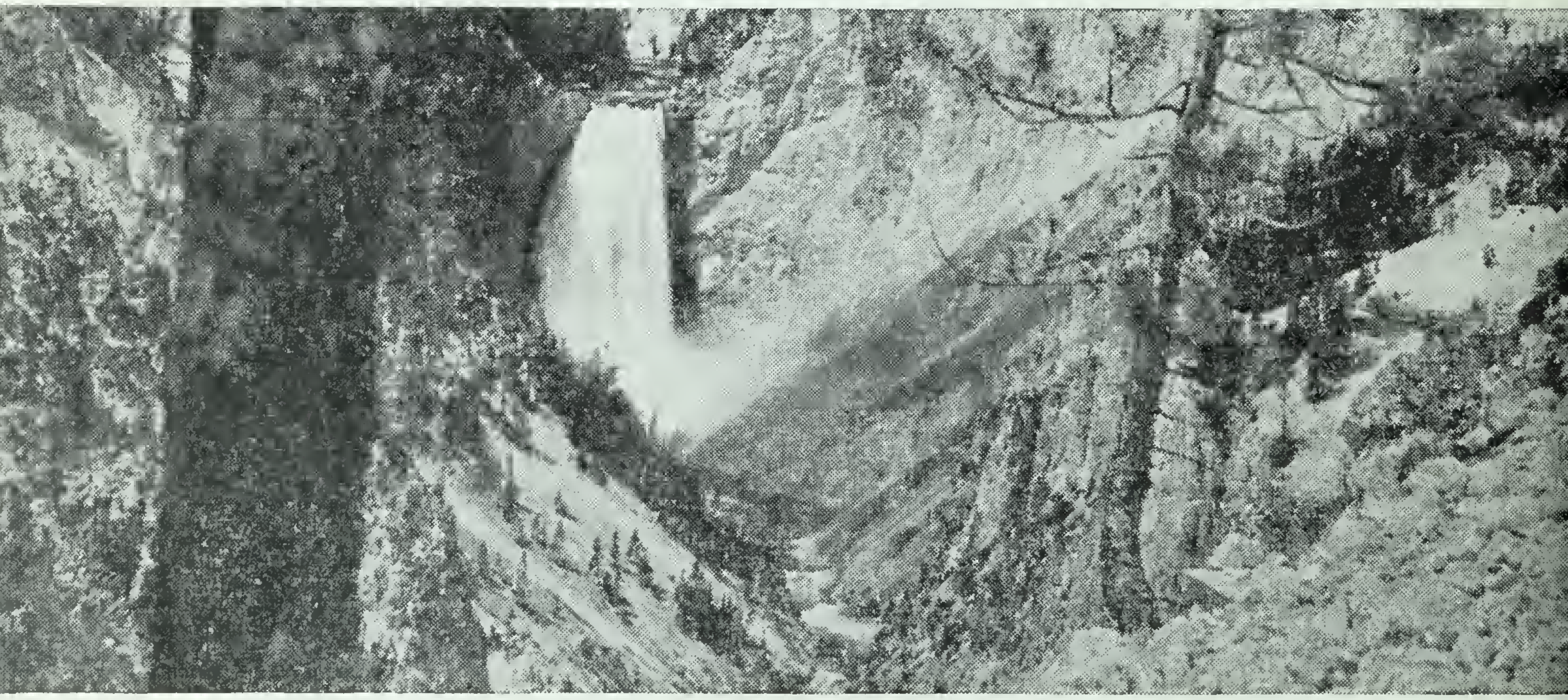
Heat a sample of humus soil in the crucible, and observe changes which take place in it. If a delicate balance is available, weigh the sample before and after heating it.

What was observed: Describe results observed, and record your measurements.

What was learned: What soil holds the most water. Of what is soil made?

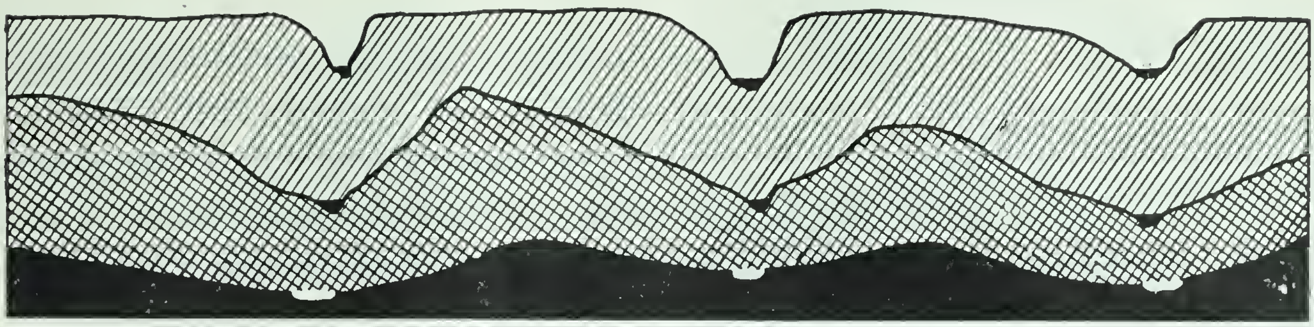
Exercise. *Write a paragraph summarizing this problem, using in it the following words:* residual, transported, lichens, clay, humus, sand, weathering, physical, chemical, black, living things.





Top, courtesy U. S. Geological Survey; bottom, courtesy Northern Pacific Railway

The upper valley is the water gap of the Susquehanna, formed by the river cutting its way across mountain ridges. The winding St. Louis River (*center*) is carving its way into one bank and depositing material on the other. In this picture you are looking downstream. The falls of the Yellowstone (*bottom*) are caused by a resistant layer of rock.



Running streams cut valleys into plateaus. Then the sides are washed down, and the valleys become wider. Finally the hills disappear, and the country becomes gently rolling.

9. How does solar energy erode the earth?

When the first drop of water trickled down the hot rocks of the ancient earth, erosion began. And erosion will continue until the last drop of water has become a part of the eternal ice that will form when solar energy ceases.

What is erosion? Erosion is defined as the breaking down, wearing, and movement of materials of the earth's crust. It differs from weathering in that eroded materials are moved by some outside agent to a new place. Erosion results from large, mechanical movements of water, air, or ice. Any wearing action which results in transportation of soil and rock materials is erosion.

What forces cause erosion? Erosion results from friction of moving objects in contact with the earth's surface. The constant pounding of rocks by water and moving solid particles causes erosion. The sun provides the potential energy stored in water at elevations. That is, when a water drop forms in a cloud, it has energy because of its position. This energy is released as kinetic energy when the drop falls upon your front lawn and loosens soil. Additional potential energy is released when water flows downhill. The source of the energy is the sun, but it is gravity that causes its release as kinetic energy.

We know that there would be no erosion if there were no land exposed above sea level. The movements of the earth's surface result from the action of solar energy. It also causes constant shifting of materials—rocks, ice, and water—upon the surface. These changes in position produce changes of weight, and the crust shifts to adjust to the changing pressure

Courtesy U. S. Geological Survey

These sandstone rocks are all that remain of a much larger bed. Note the tilt of the layers. Why does the rock become wider at the top? Where did the rock in the foreground probably come from?

of the rocks. According to one theory of crust movement, the mountains are formed from the lightest rocks. Rising of land to a considerable elevation is an essential condition for erosion.

How does water act as an erosive agent? The first erosive action of rain is, of course, its breaking effect on loose soil. But most of the effect of water is from stream erosion. The factors determining the rate of stream erosion are the amount of water, the steepness of the slope, the type of rock and soil, the amount of vegetation cover, and the number of settling or still places present.

You know that the lifework of a river is to drain and wear away the land. In doing this, a stream passes through three distinct stages: youth, maturity, and old age. A young river begins by cutting a channel in which it may flow. This channel is cut down fastest at the point of greatest fall (if the rock is of fairly uniform hardness) and wears itself deeper. The falls or rapids travel upstream as the rocks crumble along the crest and below the falls. In the large rivers, such as the Niagara, the huge blocks of rock which fall from the crest are easily seen and create considerable damage at times to power projects. The valley is also deepened by scouring and wearing the bottom of the stream bed by rock carried in the stream. When layers of harder rock are encountered, they last for some time causing falls. The stage of youth lasts as long as the sides of the valley are V-shaped.

In maturity the valley sides are distinctly sloping, but the slopes are rounded and gradual. A mature valley has flood plains—that is, areas flat enough that they may be covered with flood waters for some distance from the channel. Upon this flood plain the river wanders and curves, cutting into the banks on either side. This action is called meandering.

Meandering results from the inertia of the water, which tends to flow in straight lines. When water starts in any given direction, it continues in that direction until it strikes an obstruction. The obstruction usually is the side of the valley. The water is there turned aside, and starts in a new direction.

In old age a river has a valley that is scarcely different from a plain. The flood plain is exceedingly broad. In some rivers the amount of meandering is so great that channels may shift over distances of a hundred miles or more. Meanders become so widely curved that the water cuts across the neck of land between curving sections of the river, leaving the old channel as an ox-bow lake. The channel of an old river is sometimes built up by sediments more rapidly than it is worn down by the current. As a result, the river eventually is running along a ridge, from which it escapes in time of a flood to cut a new channel. Swamps along old rivers are the normal situation. In fact, drainage in some regions may be away from the river and toward the swamps, because of the height to which river banks have been built up.

A single river may have along its course all three stages at the same time. The general situation is that young valleys are common along tributary and source streams. Along the middle stretches the river is mature. It is when the river crosses the coastal plain that it is in old age. The stage of maturity is affected greatly by the rate of rising or falling of the land. If land is rising, rivers tend to remain in youth. If it is sinking, old age approaches more rapidly than is normal.

How does ice act as an erosive agent? Ice erodes rock by several means. In glaciers its weight breaks rocks. It carries huge boulders, fine sand, and gravel, and employs all these cutting agents to erode rocks over which it passes. Clear ice scours and polishes rocks to a glasslike surface.

Materials are carried mixed into the ice and along the top of a glacier. Much loose material is pushed along ahead of the glacier, and other material is pushed out sidewise. In any region which has been acted upon by glaciers, deposits of these materials are studied to locate the exact course and extent of the ice. The materials left by glaciers are called

Photo by U. S. Forest Service

The mountains of the eastern United States are much older than those of the West. Consequently they are rounded and lower because of the greater amount of time erosive forces have acted upon them.

moraines. Moraines formed by different means are different in position and shape.

There have been, and are, two types of glaciers: mountain and continental. Mountain glaciers are found on many peaks in the Rocky and Cascade ranges in this country, in the Alps of Europe, and in many other regions. The remains of the continental glaciers are found in each of the polar regions. At one time the thickness of the last continental glacier may have exceeded half a mile.

How does wind act as an erosive agent? Wind has one effective action—that is, it blows sand which acts as a cutting agent. Such erosive action is important only in desert regions and along sea, lake, or river shores where there is an abundance of sand.

Wind indirectly erodes land along the seashore because of the action of waves. Along the famous chalk cliffs of Dover in England are old roads which once were safely back from the ocean, but which today run along the cliffs to end at the ocean edge. Entire farms have fallen into the sea as the waves cut the cliffs away beneath them.

Courtesy U. S. Department of Agriculture

At the top of this gully are the remains of a cornfield. Has the gully been formed suddenly or over a number of years? Gullying is an extreme form of erosion but not an unusual one.

Is all erosion harmful? Most of the rich soil of the lower Mississippi Valley, of the slopes of the Great Plains, and of the Coastal Plains was brought from other regions and deposited. The rich Red River Valley of North Dakota and Minnesota is an ancient lake bed, built up of materials transported from Canada. This ancient lake, Lake Agassiz, was filled by waters from the melting continental glacier, and disappeared when the ice melted sufficiently to permit the water to drain northward. Many other flood plains, lake beds, and valleys similarly consist of transported soil.

Exercise. *Complete the following sentences:* Water in clouds contains —1— energy obtained from the —2—. This is released by the force of —3—. Rivers cut into their banks because of the —4— of running water. The —5— rocks are forced upward to form mountains. The wandering and curving of a river on its flood plain is —6—. Rounded hills, quick runoff, and good drainage are characteristic of —7— rivers; flat valleys and slow runoff

of —8— rivers; and steep-sided valleys and rapids of —9— rivers. The ice caps around the poles are part of the —10— glaciers.

10. How can we conserve the soil?

Although the forces of weathering and erosion have produced the soil, they also destroy it. While it is a matter of little importance in the history of the earth if the soil washes away, it is of utmost importance to us that we keep erosion from destroying valuable farm lands. We must keep the earth fit for the plants which provide our food.

How may erosion start? Erosion occurs at any point where the covering of the soil is removed sufficiently to permit water, wind, or weather to act directly on the soil.

The covering of the earth has been removed by man in cultivating the soil, in cutting the forests for lumber, and in clearing land for agricultural use. Many animals destroy the protective plant covering. Grasshoppers leave the soil bare of plants. Prairie dogs dig deep holes in which erosive forces act. Sheep and cattle graze so closely that they destroy the grass. Many grazing animals, particularly deer and sheep, eat small shrubs and trees.

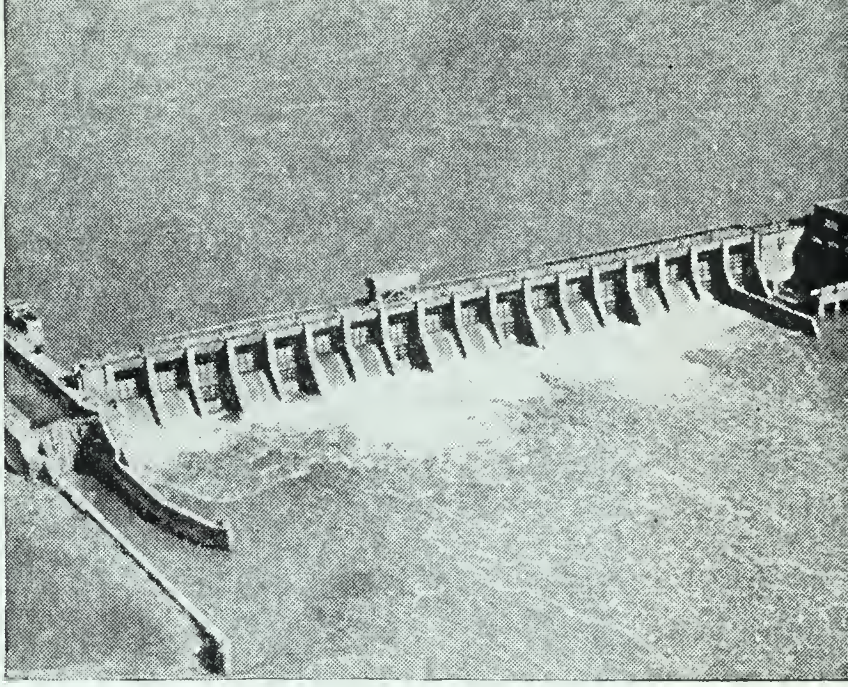
Fire is the worst of all destroyers of the plant cover of the soil. A single fire may destroy a forest many square miles in extent, killing trees that may not be replaced in one or two hundred years.

The importance of plants in protecting soil can hardly be overstated. Their leaves break the force of rain. Leaf mold holds water. Plants break the force of wind, preventing soil from being blown away. Trees shade the snow in spring and prevent rapid melting and runoff. Roots of trees and plants may serve to hold soil and stop the formation of gulleys.

There is hardly a large section in the United States where erosion is not a genuine threat to our food supply.

What are the commonest types of erosion? Running water is of course the greatest erosive agent. During a heavy rain, water often runs in a sheet over a field and removes a thin layer of soil from the entire field. The more sloping the field, the greater is the amount of soil that is removed. It is a

common observation of farmers that hilltop and hillside fields are not as fertile as the lower lands. In fact the term "rich bottom lands" is a typical way of recognizing this difference. The fertile soil from the hills has been washed down into the bottom lands. Much fertile soil is carried into the streams and is lost. If you have seen a stream flowing through a plowed field and another flowing through a sodded meadow, you can well appreciate the loss of soil by rain erosion. The water in the first stream is brown, that in the second crystal-clear.



Courtesy Chattanoogans, Inc.

The great Tennessee Valley Authority project has not only conserved soil over a vast area but has produced power from water which formerly ran off in great floods.

Gully erosion results when the water forms small valleys. A gully is really the beginning of a young valley. While it is true that it is the lifework of a stream to wear away and drain the land, the problem becomes serious if you happen to own the land and depend upon it for a living. And all of us really depend upon the land for a living. A gully may start in a small footpath, spread into a neighboring field, cut a wide hole in the field, wear itself deeper, cut back until the field is destroyed, undercut its banks causing the farmhouse and barn to fall into the hole, and destroy the farm so completely that it is unfit even for growing trees. Similar erosion happens not to one but to hundreds of farms. In many of the hilly regions of southeastern United States, where originally the land was fertile, there are practically no farms capable of supporting their owners.

Stream erosion occurs continually along all streams. It is most destructive of farm lands in flood season. Streams may deposit deep layers of sand and gravel over productive land and spoil its fertility. They may wash away trees and other vegetation and remove all the fertile soil.

When occasionally rain falls in deserts, erosion is more rapid there than in moister regions. There is little protective

Kenneth M. Wright photo

Dams built by beavers hold water that would otherwise run off. In these quiet ponds sediment settles, vegetation grows, and eventually soil is formed. Many mountain meadows were originally beaver ponds.

vegetation in deserts. Because most of the deserts in the United States are situated in elevated regions, the runoff is rapid and destructive.

Wind erosion has been a problem in some regions since the last glacier melted. Where drought kills native grasses or cultivation removes them, the bare soil is blown like snow, forming drifts, darkening the sky, sometimes choking and smothering animals, and destroying the value of the land. The desert states and dry states of the Southwest are most troubled by dust storms. Wind erosion can destroy the value of a farm in two or three years.

How is erosion controlled? Probably the most important single means of erosion control is through proper cultivation. There are many ways of cultivating soil to retard erosion. For example, if a hill is plowed in such a way that the furrows run from top to bottom, each furrow acts as a small valley down which water can run, carrying soil with it. If, on the other hand, the plowing follows the side of the hill, so that the earth is thrown up the hill and each furrow maintains the same elevation around the hill, the furrows act as

dams. This method is called contour plowing. The water is held behind these dams until it has a chance to soak into the soil. Where a gully has started, a ridge of soil may be thrown across it to retard the flow of water. Since sediment settles in still places, every quiet pool, however small, is a soil saver.

On steeper hillsides, the soil may be terraced. There are regions in China and in the Philippine Islands where rice fields are terraced. The fields lie one above another like stairsteps. Terracing requires work and engineering skill to prevent the edges of the terraces from becoming waterfalls which speed up erosion. The terraces, if properly placed, may be made of earth. In the steepest places stone, wood, or concrete may be used to hold the soil.

All fairly steep slopes should be planted in some permanent crop, preferably a perennial of the clover or alfalfa type, which will form a deep root system and remain in place for years. If such crops will not grow on the soil, it should be planted to some native grass or to shrubs which will provide protection for birds and wild game. Most slopes can be converted eventually into wood lots.

Grazing should be carefully controlled. Before the ground is bare of grass, cattle should be removed to other grazing grounds. Fires should never be started where erosion might result.

Gully erosion may be stopped by cutting down the sides of the gully and planting them with trees and shrubs. It may be necessary to build stone, wood, or brush dams where the slope is too steep for plants to grow.

In small streams use of dams equalizes the water supply and causes all sediments to be deposited. Building large dams stops the cutting of a river into its valley and slows the cutting of side streams. In forests where enough trees are available, beavers are among the best erosion-control agents. They build dams which cause lakes to form. These lakes fill up and become wide meadows. Since beavers eat the bark of trees, they are of value only where there is enough food for them without destroying valuable timber.

It is the responsibility of the state to provide experts to inspect farms and to educate farmers as to the need of con-

Courtesy Caterpillar Tractor Co.

Proper cultivation prevents erosion and loss of water. The upper field has been cultivated to form ridges which hold snow needed for moisture. The lower field retains a heavy rainfall which under poor cultivation would have run off, leaving gulleys and dryness behind.

trolling loss of lands. The state can well afford to supply trees to farmers. The federal government has made direct payments to farmers who plant erosion-controlling crops on their farms. While it may be the course of natural events for solar energy to wear away the earth, it is our responsibility to protect those parts which we need. The soil contains our most valuable mineral wealth. Already, too much of it has gone down to the ocean, where the plant food is dissolved, and the soil settles to form sedimentary rocks for future ages.

Filmstrip: Soil erosion, a national menace. U.S.D.A.

Exercise. *Complete the following sentences:* Wearing away the land and transporting solid materials is called —1—. A major factor in causing it is man's —2— of the soil. —3— destroys the

humus in soil. —4— by animals may cause erosion. Washing a thin layer of —5— from fields is the cause of barren hilltops. A small valley formed in soil is called a —6—. In dry countries erosion by —7— occurs. If land is —8— around hillsides, washing is slowed. Continuous cover should be provided for all —9— ground. Use of —10— in streams reduces erosion.

A Review of the Unit

Solar energy was responsible in some way for the existence of the earth, and it has been responsible for the changes in the earth that have made it as it is today. Some of the changes that have occurred in the earth have resulted when solar energy is lost by cooling as the rocks solidify and contract. Other changes occurred when the earth was changed by erosion and weathering. All movement of air and water upon the earth are caused either by changes in the amount of energy they contain or by rotation. Man has little control of the effects of solar energy except to protect himself from the weather and to protect the soil from rapid erosion.

An exercise in thinking

Match the principles and related ideas, according to the directions given in the review at the end of Unit I.

List of principles

A. The sun provides energy to produce changes in the materials which make up the earth.

B. The sun provides energy for living things upon the earth.

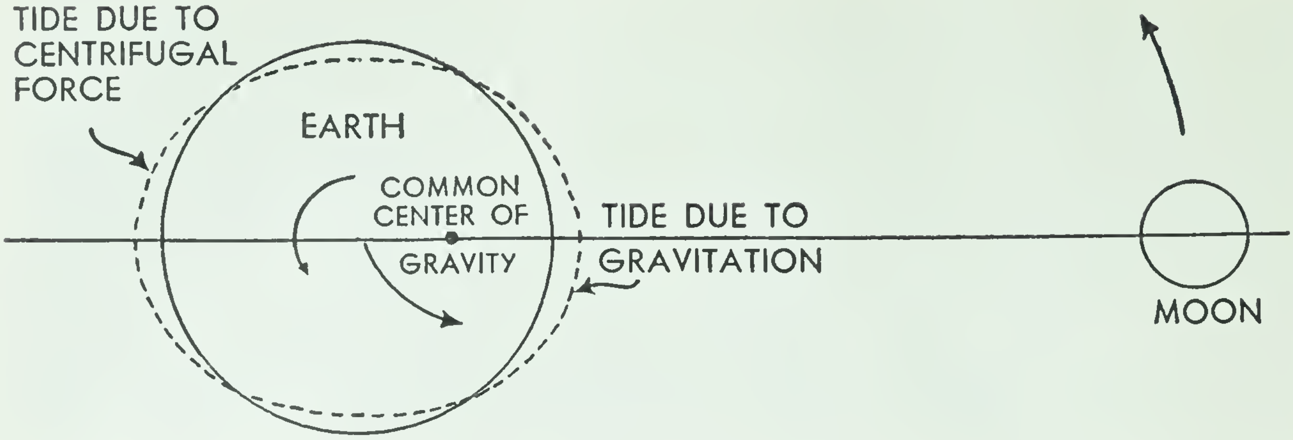
C. The rate of absorption of solar energy is dependent upon the angle of the absorbing surface.

D. Action of gravity upon objects and substances lifted by solar energy produces mechanical movement.

E. The gravitational pull of one object upon another is in proportion to the mass and inversely in proportion to the square of the distance between them.

F. An object at rest remains at rest, and an object in motion remains in motion in the same straight line, unless acted upon by an outside force.

G. The state of matter depends upon the amount of energy in it.



The tide on the side of the earth toward the moon is caused by gravity, while that on the opposite side is caused by centrifugal force.

List of related ideas

1. Heat of the sun causes rocks to expand and break.
2. Cirrus clouds, which are the highest above the earth, are composed of ice.
3. The outer bank of a curved river is cut away.
4. The igneous rocks of the ancient earth are now metamorphic rocks.
5. Coal contains energy which may have come from the sun 60,000,000 years ago.
6. Quartzite is a metamorphic form of sandstone.
7. The polar regions are colder than the tropical regions.
8. When the earth turns, the atmosphere lags behind, producing winds.
9. The earth revolves around the sun instead of flying out into space.
10. The earth does not fall into the sun, but revolves around it.
11. Rain occurs when a cold air mass pushes a warm air mass upward.
12. Glacial ages occur when the earth is colder than usual.
13. Young rivers cut narrow, deep valleys and go over falls.
14. The presence of very simple fossils in ancient rocks indicates that life has existed for hundreds of millions of years.
15. The cluster of stars making up the galaxy in which the sun is located does not seem to be scattering.
16. The North Star, which is about 450 light-years distant, has little effect on the earth.
17. As falling air becomes warmer in the horse latitudes, it evaporates water and causes deserts.
18. Warm air is lighter than cold air.
19. Air pressure is measured by the barometer, which contains mercury.

20. When the earth moves, the weight of the seismograph stands still.
21. It is hotter in July than in January in St. Louis.
22. Neptune, by revolving around the sun once in 165 of our years, is able to remain in its orbit.
23. Wind and waves constantly change shore lines.
24. The formation of huge glaciers reduces the level of the ocean.
25. There are seasonal variations in solar energy.
26. Cold air masses force their way under the warm air masses.
27. As air rises, the water vapor tends to condense.
28. Erosion is the wearing away and breaking of the earth's crust.
29. We depend upon plants for our food supply.
30. The sedimentary rocks are formed from materials produced by erosion.
31. The sun makes the ground hotter at noon than at evening.
32. The moon does not fall on the earth because of its speed of revolution.
33. The moon revolves around the earth because of the earth's attraction.
34. An old river has a flat valley in which it deposits material.
35. Condensation of water vapor warms the surrounding area.
36. Growth of green plants occurs chiefly in the daytime.
37. Ground water dissolves limestone rocks to form caves.
38. South slopes are warmer than north slopes.
39. The carbon dioxide-oxygen cycle provides plants and animals with essential gases.
40. A glacier causes erosion by slowly flowing downhill.

Some things to explain

1. What kind of weather would you expect if you were to read in the paper that a polar air mass is approaching on March 1?
2. Why is a shooting star really not a star?
3. If you find a deposit of fossils in your community, what would be the best way to insure its proper study?
4. Why is conservation of plants and animals so closely related to soil conservation?
5. Is there any real evidence that the earth is as old as is claimed?
6. How will the earth probably come to an end, if it ever does?

Some good books to read

Baker, Robert H., *The Universe Unfolding*
Book of Popular Science, Grolier Society
Brooks, C. F., *Why the Weather?*
Compton's Pictured Encyclopedia
Federer, C. and H. J., *Splendors of the Sky*
Heal, Edith, *How the World Is Changing*
Humphreys, W. J., *Weather Proverbs and Paradoxes*
Jeans, Sir James, *The Stars in Their Courses*
Kay, G. F., *The Last Million Years*
Lewis, Isabel, *Splendors of the Sky*
Lucas, Jannette, *The Earth Changes*
Morrel, M. M., *When the World Was Young*
Pickwell, Gayle B., *Weather*
Pirsson, L. V., and Knopf, A., *Rocks and Rock Minerals*
Reed, W. M., *The Earth for Sam*
Reed, W. M., *Stars for Sam*
Van Cleef, Eugene, *The Story of Weather*
World Book Encyclopedia

Some interesting motion pictures

Our Earth. De Vry (*16 silent*)
Formation of Soil. Eastman (*16 silent*)
Work of the Atmosphere. Erpi (*16 sound*)
Earthquakes. Films of Commerce (*16 silent*)
Volcanoes. Eastman (*16 silent*)
The Work of Rivers. Erpi (*16 sound*)
Back of the Weather Forecast. (2 reels) U. S. Department of Agriculture (*16 silent*)
Weather Forecasting. Eastman (*16 silent*)
Climate. Edited Pictures (*16 silent*)
The Earth in Motion. Erpi (*16 sound*)
Exploring the Universe. Erpi (*16 sound*)
The Moon. Erpi (*16 sound*)
Seeing the Universe Through the World's Largest Telescopes. (5 reels). Educational Film Library (*16 silent*)
The Solar Family. Erpi (*16 sound*)
Earth and Its Seasons. McCrory (*16 sound*)

Some related lantern slides

Astronomy. Keystone View Co.
The Earth's Crust. Keystone View Co.
Weather and Climate. Keystone View Co.

SOME SCIENCE WORDS

This list includes all the words for which *pronunciations* and *formal* definitions are given in the text. The page numbers refer to those pages on which the words are pronounced or defined. Where a definition is omitted in this list, it means that the word is pronounced and *informally explained* on the page given, and therefore no *formal* definition is added here. See page viii in the front of the book for an explanation of the method of pronouncing and defining the words in this book.

adrenal glands, glands situated on top of the kidneys (p. 330).

aileron, one of the controls of an airplane (p. 557).

amoeba, p. 57.

amphibian, p. 71.

anemia, a disease caused by an inadequate supply of iron or improper use of iron in the body (p. 308).

anesthetic, a drug which causes loss of feeling (p. 468).

Archeozoic era, the first era during which there was life on the earth (p. 740).

arthropods, animals with jointed feet (p. 63).

autonomic, p. 339.

bauxite, p. 158.

calorimeter, p. 154.

cambium, p. 49.

Cenozoic era, the most recent era when animals appeared on earth (p. 742).

centrifugal, p. 364.

cerebellum, part of the brain located under the back part of the cerebrum (p. 339).

cerebrum, the forebrain (p. 339).

chameleon, p. 72.

chitin, p. 63.

chlorophyll, p. 43.

chronometer, p. 578.

cilia, hairlike growths on cells used to produce movement (p. 58).

commutator, p. 192.

conifers, plants that bear their seeds in cones (p. 56).

convection, p. 145.

crustacean, p. 65.

diaphragm, p. 321.
dinosaurs, huge reptiles of the Mesozoic era (p. 741).
dirigible, p. 550.

enzymes, chemicals found in the digestive juices (p. 315).

frond, leaf of the fern plant (p. 54).
fuselage, the body of an airplane (p. 557).

Galen, a Greek physician who lived around 200 B.C. (p. 469).
Gila monster, p. 72.
gyroscope, a toplike wheel which spins with sufficient inertia to keep it from being turned rapidly (p. 559).

hemoglobin, a chemical which combines with oxygen in the lungs to change the color of the blood (p. 321).
Hippocrates, a Greek physician who lived around 400 B.C. (p. 469).

hypothesis, p. 5.

incandescence, hot enough to give off light (p. 236).
inertia, p. 105.

Koch, a German scientist who lived around 1900 (p. 470).

lichen, a dry, scalelike plant (p. 37).
Linnaeus, a Swedish botanist who lived around 1750 (p. 56).

Mesozoic era, the era of intermediate life on earth (p. 741).
metabolism, the process of using food and releasing energy (p. 34).

nucleus, the central part of a cell (p. 33).
nutrients, p. 288.

opaque, p. 232.
orthochromatic, p. 265.

osmosis, the process by which water passes through the walls of root hairs (p. 48).
oxyacetylene, p. 164.

Paleozoic era, the era of ancient life on earth (p. 741).
paramecium, p. 58.
parasites, fungi that use living matter for food (p. 52).
percussion, a type of musical instrument (p. 596).
petioles, leaf stalks (p. 50).
photosynthesis, the process by which food is made (p. 42).
pituitary gland, gland located deep in the skull (p. 330).
Proterozoic era, era of early life on earth following the Archeozoic era (p. 741).
protoplasm, p. 33.
ptarmigan, a bird which lives high in the Rocky Mountains (p. 87).
pulmonary, pertaining to the lungs (p. 321).

radiometer, p. 149.
rarefaction, p. 589.
rectifier, a device to change alternating current to direct current (p. 221).
residual soil, soil which remains where it is formed (p. 766).
resonance, a resounding (p. 598).
rheostat, p. 221.

saprophytes, fungi that use dead matter as food (p. 52).
Semmelweiss, a Hungarian physician who lived around 1850 (p. 469).
sequoias, p. 56.
sidereal time, the time obtained by observing a star (p. 579).
solder, p. 165.
sperm, part of a plant needed by the egg to help it grow (p. 54).
static, to stand still (p. 174).
sulfanilamide, p. 493.

thallus plants, p. 54.
thermostat, p. 443.
tourniquet, a broad band of cloth tied loosely around a limb (p. 487).
transpiration, p. 45.
tropism, p. 40.
tubules, p. 325.

Van Leeuwenhoek, a Dutch naturalist who lived around 1670 (p. 469).
Vesalius, a Belgian anatomist who lived around 1540 (p. 469).
virus, a disease-producing protein chemical (p. 469).

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